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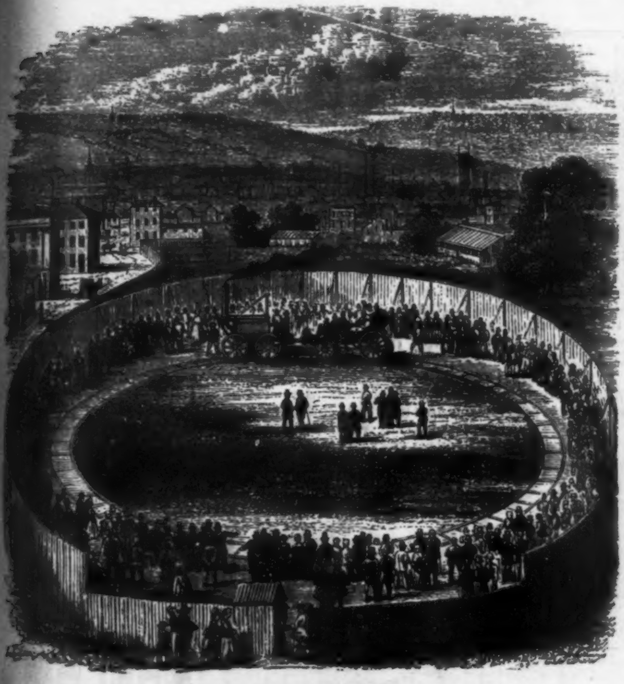
[THE GRAPHIC.]

THE DEVELOPMENT OF RAILWAYS IN ENGLAND.

By F. McDERMOTT.

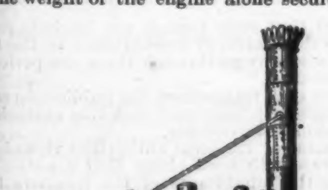
ALTHOUGH George Stephenson is rightly regarded as the "Father of Railways," for it was he who made the locomotive a practical success for traffic, the idea of a steam engine for traction had been previously worked out by, among others, the Cornish miner Trevithick, who, in 1808, laid down a circular railway in a field adjoining the New Road, now part of Euston Square, where his locomotive drew a carriage at the rate of twelve miles an hour.



TRIAL OF TREVITHICK'S ENGINE ON A CIRCULAR RAILWAY IN A FIELD NEAR THE NEW ROAD, LONDON, 1808.

Hedley's Puffing Billy, which successfully proved that the weight of the engine alone secured sufficient "bite" on the rails without the appliances which had previously been considered necessary, also forms an important link in the development of the locomotive. The escape of the jets of steam at high pressure caused, however, so much annoyance to the owners of horses in the neighborhood that the engine had to be stopped whenever a cart or carriage approached, and the working of the traffic was thus seriously interrupted until the manners of Puffing Billy were improved by an ingenious arrangement for allowing the steam to escape gradually.

By 1815 George Stephenson had made several important changes in the construction of the locomotive, and the mechanism had, as will be seen from the accompanying sketch, been considerably simplified. His engine, Locomotion, which was the first to run on the Stockton and Darlington line in 1825, weighed about eight tons, and could make a speed of nearly sixteen miles an hour—or somewhat less than the work of a good bicyclist—the chimney often becoming red-hot in the performance. The Stockton and Darlington line, however, was originally built entirely for mineral traffic, the passenger business being a subsequent development, and it was not until the opening of the Liverpool and Manchester line that the vast possibilities opened out in this direction by the iron horse were realized. Even at that time, ideas as to the construction of locomotives varied very considerably, and there were so many different engines in the field that a competition to test the merits of the various systems was arranged. A large stand was erected for the ladies at Rainhill, near Liverpool, and vast crowds assembled to witness the contest. The "course" was a level piece of railroad about two miles in length, and each engine was required to make twenty trips in the course of the day, at an average speed of not less than ten miles an hour. Of the four engines entered for the competition, one could not do more than five or six miles an hour, and was consequently "scratched" at an early stage of the proceedings; two others broke down; and George Stephenson's Rocket—which weighed, with its supply of water, only 4¼ tons—was thus triumphantly victorious. It had indeed far exceeded the expectations of the public, having drawn a coach with thirty passengers at about thirty miles an hour. This same Rocket, long after it had been superseded by heavier engines, on one occasion ran four miles in four and a half minutes—a very creditable record for nearly sixty years ago. Important changes in the form of locomotives were made after the opening of the Liverpool and Manchester line, and by 1838, or just fifty years ago, the locomotive had assumed the shape and main characteristics of its descendants of to-day.

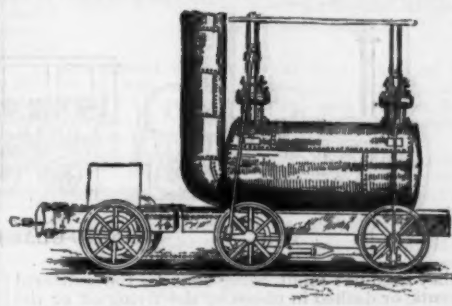


GEORGE STEPHENSON'S ROCKET.
Victorious in the great Engine Contest at Rainhill, 1829.

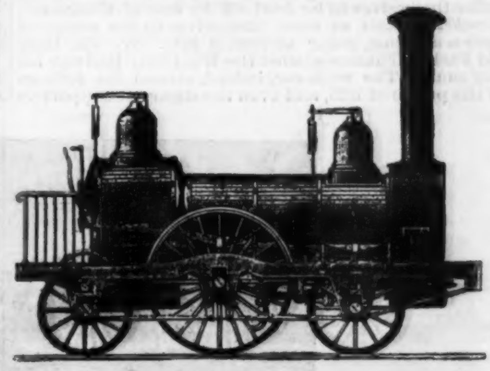
PUFFING BILLY, 1813.

COMPETITION OF LOCOMOTIVES AT RAINHILL, 1839—THE ROCKET COMES IN FIRST.

There are still some of us who can well remember scenes like those depicted in our recent "Coaching Days" series, and who can yet recall the incredulity and scorn with which a large section of the public received George Stephenson's expectations that his engines would run twelve or fourteen miles an hour on the Stockton and Darlington line. The country gentlemen thought that the smoke would kill the birds that might happen to pass over the locomotive; the manufacturers expected that the sparks from the engine would set the country, and their goods in particular, on fire; horses would be constantly taking fright, foxes and pheasants would soon be as extinct as the dodo, the breeding of horses would cease, the hurry and excitement would spoil the milk of cows that had to graze near the lines, in whose vicinity vegetation would languish, and the engines would burst, or the wind, the rain, and the snow would stop them.



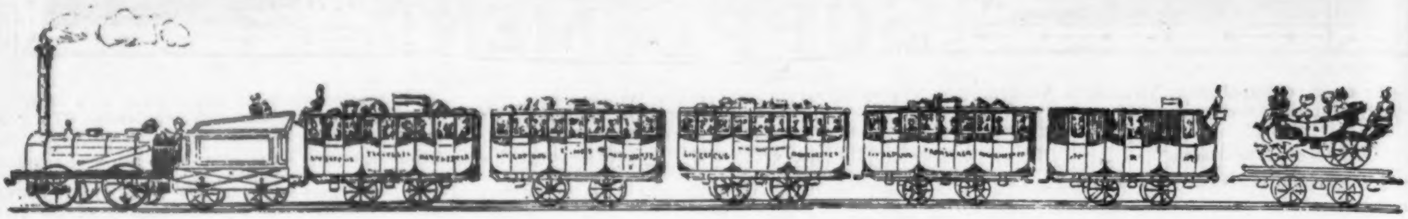
GEORGE STEPHENSON'S ENGINE, 1815.



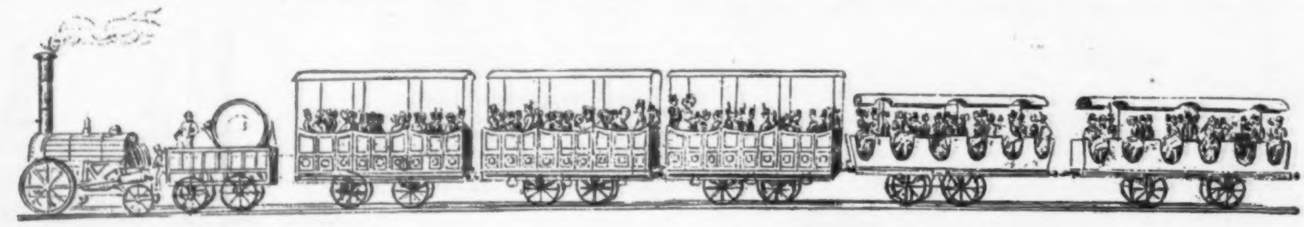
ENGINE, BIRMINGHAM AND DERBY JUNCTION RAILWAY, 1838.

The *Quarterly Review*, referring to a proposal to build a line to Woolwich, said: "The gross exaggera-

tion of the powers of the locomotive steam engine, or, to speak more plainly, the steam carriage, may delude for a time, but must end in the mortification of those concerned. It is certainly some consolation to those who are to be whirled at the rate of eighteen or twenty miles an hour by means of the high-pressure engine, to be told that they are in no danger of being seasick while they are on shore, that they are not to be scalded to death, nor drowned by the bursting of the boiler,



FIRST-CLASS TRAIN ON LIVERPOOL AND MANCHESTER RAILWAY, 1837.



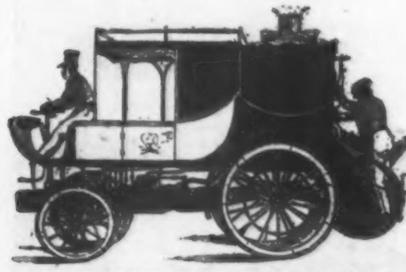
SECOND-CLASS TRAIN ON LIVERPOOL AND MANCHESTER RAILWAY, 1837.

that they need not mind being shot by the scattered fragments, or dashed in pieces by the flying off or the breaking of a wheel. But, with all these assurances, we should as soon expect the people of Woolwich to suffer themselves to be fired off by one of Congreve's *ricochet* rockets as trust themselves to the mercy of such a machine, going at such a rate. We will back old Father Thames against the Woolwich Railway for any sum." The reviewer, indeed, echoed the feelings of the public of 1825, and even the strongest supporters

STEAM *VS.* HORSES.

of railways took a very modest view of their future. One of the leaders of the party wished it to be clearly understood that they did not sanction "the ridiculous expectations, or rather professions, of the enthusiastic speculator who expects to see the engine traveling at the rate of twelve, sixteen, eighteen, or twenty miles an hour." The Stockton and Darlington line was laid out with the idea that the passengers would be drawn by horses as on our modern tramways, only the minerals and goods being left to the tender mercies of the locomotive. The man on horseback who, until the engine developed a dangerous speed, marched, as shown in the sketch on page 10746, in front of the first train on that line, thus typified one of the motive powers to be used.

It is indeed impossible for the present generation to realize the alarm with which the introduction of the locomotive was viewed by a large section of the public. Science was invoked to show the dangers to health



MACIRONE'S STEAM CARRIAGE.

from such unnatural performances. Thus, the editor of a semi-scientific journal wrote:

"It has been gravely talked of lighting tunnels artificially, so as to supersede the necessity of daylight. How, or by what means, this is to be done remains a secret. To philosophers and practical men, the hopelessness of approaching the solar by any artificial light is well known. . . . Coarse as our optical nerves are in judging of degrees of light, it would therefore be impossible to have a sudden transition from solar to lunar light without producing the sensation of great darkness. But it is not the transition from light to darkness which is anything so bad as the contrary—from the intense tenebrosity of a tunnel to the full broad glare of daylight. . . . Let us suppose, from having been shut up within a coach in a tunnel for a few seconds, the pupils of the eyes had attained their utmost distention; and let us for one minute consider, in the state of this unusual distention to nine or ten times their natural size, that a light, from 500,000 to probably 1,000,000 times greater than that of a mould candle, was all at once to burst upon so delicate an organ! I appeal with confidence to any medical man to answer the question of the effect—particularly if often repeated—on a tender constitution and sight!"

Perhaps this neglected warning may throw some light on the steady increase in the use of glasses among the rising generation. There were, however, terrors of a more immediate and striking character associated with these subterranean journeys. One gentleman who had dared "the desperate thing," said the "chill of a two miles' subterraneous passage would deter any person of delicate health from ever venturing therein; as he would be by the resounding echo of the rattling wheels, the puffing of a high-pressure engine, and clinking of chains in the utter darkness, or by the dismal glare of lamps, which convey a horror which weak nerves could never endure."

So general, indeed, was the fear of tunnels that a commission composed of some of the leading physicians of the day was appointed to report on the Primrose Hill tunnel of the London and Birmingham (the present London and Northwestern) Railway. Happily these medical travelers did not see such appaling dangers and diseases in such brief sojourns underground as more timid passengers discovered, and they reported that:

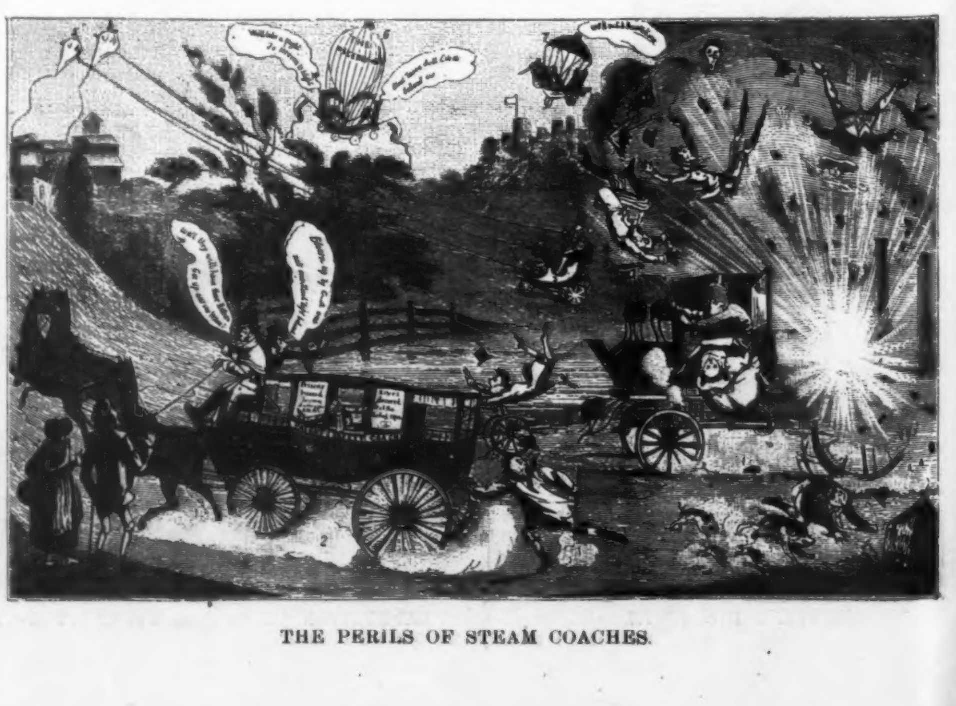
"We found the atmosphere of the tunnel dry, and of an agreeable temperature and free from smell. The lamps of the carriages were lighted, and in our transit inward and backward again to the mouth of the tunnel the sensation experienced was precisely that of traveling in a coach by night between the walls of a narrow street. The noise did not prevent easy conversation, nor appear to be much greater in the tunnel than in the open air. We are, in short, decidedly of opinion that the dangers incurred in passing through well-constructed tunnels are no greater than those in ordinary traveling upon an open railway or upon a turnpike road, and that the apprehensions which have

CHURCH'S STEAM CARRIAGE, INTENDED TO RUN BETWEEN LONDON AND BIRMINGHAM.

been expressed that such tunnels are likely to prove detrimental to the health, or inconvenient to the feelings, of those who may go through them, are perfectly futile and groundless."

Fortified with such reassurance, the public soon came to regard tunnels with less dread, and this obstacle to railway extension was overcome.

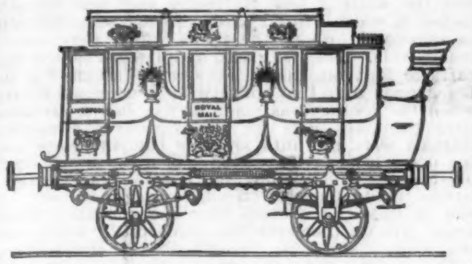
In Holland some of the local authorities viewed the new railway craze with such alarm that a notice was issued warning the inhabitants of the frontiers that they would be fined ten florins a head if they ventured



THE PERILS OF STEAM COACHES.

to go and witness the opening of a railway in Belgium! Some of this solid and obstructive spirit apparently still lingers in the bureaux of the Dutch railway administrative authorities, if we may judge by the speed and facilities of the present system.

A New York paper foresaw "what would be the effect of the railroad system—it would set all the world a-gadding. Twenty miles an hour! Why, you will not be able to keep an apprentice boy at work; every



EARLY RAILWAY CARRIAGE ON THE COACH MODEL.

Saturday evening he must make a trip to Ohio to spend the Sabbath with his sweetheart. Grave, plodding citizens will be flying about like comets. All local attachments must be at an end. It will encourage flightiness of intellect. Veracious people will turn into the most immeasurable liars; all their conceptions will be exaggerated by their magnificent notions of distance. Upon the whole, sir, it is a pestilental, topsy-turvy, harum-scarum whirligig. Give me the old, solemn, straightforward, regular Dutch canal—three miles an hour for expresses, and two for jog-and-trot journeys, with a yoke of oxen for a heavy load! I go for beasts of burden; it is more primitive and scriptural, and suits a moral and religious people better."

It is, however, all very well for the present generation, who have grown up with railways existing as commonplace facts, and have seen electricity made to light our streets and houses, and enable people to talk

PROPHETIC RAILWAY MAP OF ENGLAND, 1846. (From *Punch*.)

to friends hundreds of miles away. But it was very different fifty years ago, when the "iron horse" had only just been broken in, when an old lady, who had never even heard of a railway, and who had wandered from the limits of her native parish, saw for the first time "a long, black thing, spitting out smoke, and crawling along the ground," and finally, on seeing her, "uttering a loud yell, and rushing into a hole in the ground." This lady's cousin in America had an even more startling tale to tell of her first introduction to the habits of the "uncanny thing." By some misfortune, the train in which this good lady was making her first journey ran off the line, and rolled down a high embankment. On recovering her senses, the traveler anxiously looked round to her nearest neighbor in misfortune, and inquired:

"Could you kindly tell me if this is Salem?"

"No, madam," was the answer, "this is a catastrophe."

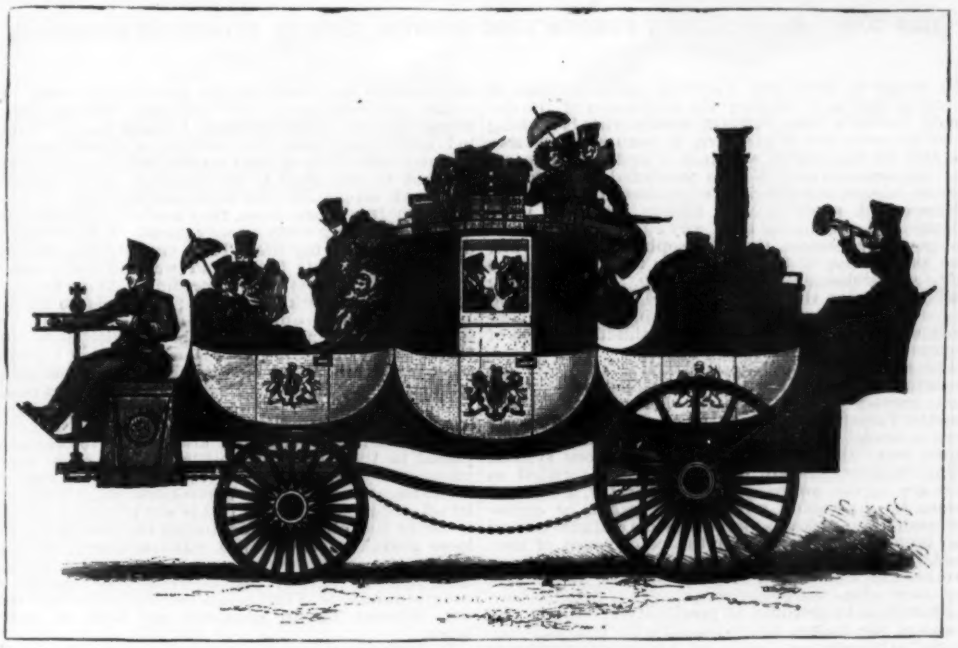
"Oh, indeed! then I hadn't orter to have got off here."

It was a relief to the poor soul to find subsequently that her first experience was not the ordinary mode of stopping of railway trains.

While, however, the general public were opposed to railways, those who realized the possibilities of this application of steam, or overcame their first prejudice and fear, were enthusiastic in their praises of the iron horse. Thus Fanny Kemble, who was acting in Liverpool at the time of the opening of the Liverpool and Manchester line in 1830, and was taken over the road by George Stephenson himself, wrote the following glowing account of her novel experience:

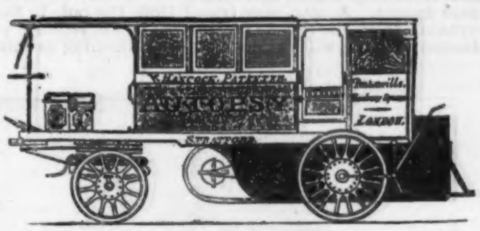
"A common sheet of paper is enough for love, but a foolscap extra can only contain a railroad and my ecstasies." Having described the starting point and rough carriages, the fair narrator proceeded:

"The carriage was set in motion by a mere push, and, having received this impetus, rolled with us down an inclined plane into a tunnel which forms the entrance to the railroad. The tunnel is 400 yards long, I believe, and will be lighted by gas. There is another tunnel parallel with this, only much wider and longer, for it extends from the place we had now reached, and where the steam carriages start, and which is quite out of Liverpool, the whole way under the town to the docks. This tunnel is for wagons and other heavy carriages; and as the engines which are to draw the trains along the railroad do not enter these tunnels, there is a large building at this entrance which is to be inhabited by steam engines of a stationary turn of mind, and different constitution from the traveling ones, which are to propel the trains through the tunnels to the terminus in the town without going out of their houses themselves. . . . We were introduced to the little engine which was to drag us along the rails. She (for they make these curious little fire horses all mares) consisted of a boiler, a stove, a platform, a bench, and behind the bench a barrel containing enough water to prevent her being thirsty for fifteen miles, the whole machine not bigger than a common fire engine. She goes upon two wheels which are her feet, and are moved by bright steel legs called



JAMES' STEAM CARRIAGE.

pistons. These are propelled by steam, and in proportion as more steam is applied to the upper extremities (the hip joints, I suppose) of these pistons, the faster they move the wheels; and when it is desirable to diminish the speed, the steam, which unless suffered to escape would burst the boiler, evaporates through a safety valve in the air. The reins, bit, and bridle of this wonderful beast is a small steel handle, which applies or withdraws the steam from its legs, or pistons, so that a child might manage it. This snorting little animal, which I felt rather inclined to pat, was then harnessed to our carriage, and Mr. Stephenson having taken me on the bench of the engine with him, we started at about ten miles an hour. . . . You can't imagine how strange it seemed to be journeying on thus, without any visible cause of progress other than the magical machine, with its flying white breath and rhythmical, unvarying pace, between rocky walls which are already clothed with moss and ferns and grasses; and when I reflected that these great masses of stone had been cut asunder to allow our passage thus far below the surface of the earth, I felt as if no fairy tale was ever half so wonderful as what I saw. . . . The engine having received its supply of water, the carriage was placed behind it, and was set off at its utmost speed, thirty-five miles an hour, swifter than a bird flies (for they tried the experiment with a snipe).



THE AUTOPSY, A STEAM CARRIAGE FOR ROAD TRAVELING.

You cannot conceive what that sensation of cutting the air was. When I closed my eyes this sensation of flying was quite delightful, and strange beyond description; yet, strange as it was, I had a perfect sense of security and not the slightest fear."

The editor of a provincial journal was equally pleased with his trip over the line, and told his readers that: "Although the whole passage between Liverpool and Manchester is a series of enchantments surpassing any in the Arabian Nights, because they are realities, not fictions, yet there are epochs in the transit which are peculiarly exciting. These are the startings, the ascents, the descents, the tunnels, the Chat Moss, the meetings. At the instant of starting, or rather before, the automation belches forth an explosion of steam, and seems for a second or two quiescent. But quickly the explosions are reiterated, with shorter and shorter intervals, till they become too rapid to be counted, though still distinct. These belchings or explosions more nearly resemble the pantings of a lion or tiger than any sound that has ever vibrated on my ear. During the ascent they became slower and slower till the automation actually labors like an animal out of breath, from the tremendous efforts to gain the highest point of elevation. The progression is proportionate, and before the said point is gained, the train is not moving faster than a horse can pace. With the slow motion of the mighty and animated machine, the breathing becomes more laborious, the growl more distinct, till at length the animal appears exhausted, and groans like the tiger when overpowered in combat by the buffalo. The moment that the height is reached and the descent commences the pantings rapidly increase; the engine with its train starts off with

THE CYCLOPEDE, FOR UTILIZING HORSE POWER.

KING HUDSON'S LEVEE. (From *Punch*.)

augmenting velocity, and in a few seconds it is flying down the declivity like lightning, and with a uniform growl or roar, like a continuous discharge of distant artillery. At this period the whole train is going at the rate of thirty-five or forty miles an hour! The scene was magnificent, I had almost said terrific. Although it was a dead calm, the wind appeared to be blowing a hurricane, such was the velocity with which we darted through the air. Yet all was steady; and there was something in the precision of the machinery that inspired a degree of confidence over fear—of safety over danger. A man may travel from the pole to the equator, from the Straits of Malacca to the Isthmus of Darien, and he will see nothing so astonishing as this.

CHAT MOSS, SHOWING THE FAMOUS LINE CONSTRUCTED BY GEORGE STEPHENSON.

The pangs of Etna and Vesuvius excite feelings of horror as well as of terror; the convulsion of the elements during a thunderstorm carries with it nothing of pride, much less of pleasure, to counteract the awe inspired by the fearful workings of perturbed nature: but the scene which is here presented, and which I cannot adequately describe, engenders a proud consciousness of superiority in human ingenuity more intense and convincing than any effort or product of the poet, the painter, the philosopher, or the divine. The projections or transits of the train through the tunnels or arches are very electrifying. The deafening peal of thunder, the sudden immersion in gloom, and the clash of reverberated sounds in confined space combine to produce a momentary shudder or idea of destruction—a thrill of annihilation."

The success of the Liverpool and Manchester line brought forward many inventions which were to give even greater results than the locomotive. At the London Tavern, for instance, was to be seen for some days a model of an invention, the motive power for which was "the rocket." By this ingenious system, "The wagons, instead of being drawn forward as they are by the ordinary steam apparatus, are placed before the propelling power. The wagon or engine containing the rocket is placed at some distance behind the wagons or carriages for the conveyance of merchandise or passengers, but connected with them by two bars of iron, which may be made of any length, and thus place the passengers at such a distance from the rocket as to preclude all possibility of danger. By means of the rocket, which has hitherto been only employed in the service of gunnery, a much greater power is derived than from steam, and the projector imagines that a speed of a hundred miles an hour may be obtained from it, without any fuel, or any of the inconveniences occasioned by steam. The projector is very sanguine in his opinions relative to the practicability of applying this power to railways, and the exhibition appears to give very great satisfaction to the scientific and other persons who have visited it."

There is a delightful simplicity about this invention thus gravely recorded by one of our oldest daily contemporaries. Why, the switchback railway and tobogganing are not to be mentioned in the same breath with it! There would, indeed, be some pleasure in railway traveling on this system—the feeling of the passengers as they sat waiting for the rocket to go off would alone make up for any hitch which might subsequently occur.

Then, again, steam was to take the place of horses on our roadways. Coaches, carriages, and carts were to be propelled by the iron horse, and to the prophetic eye, the Autopsy was the type of the means of transit of the future, so far as passengers were concerned. The proprietors of coaches tried to set their minds at rest by warning the public of the awful dangers of sitting on the top of a boiler which might at any moment explode, with results suggested in sketches, of one of which our engraving is a faithful reproduction.

While the really practical men were developing the railroad, a host of minor geniuses were in fact directing their attention to steam carriages to run on the ordinary roads. Here is one built by Dr. Church, with wheels six inches broad, and the central ones eight inches in diameter. A company was formed to run this coach between London and Birmingham and other parts. Others were built in a much lighter style; the broad wheels were thus dispensed with, and considerable success was attained. The Autopsy, for instance, made the trip to Brighton and back, and for some little time ran daily between Finsbury Square and Pentonville. Sir Charles Dance had three steam carriages running for hire between Cheltenham and Gloucester, and another at Greenwich; and Colonel Macirone's coach ran twice from London to Harrow successfully, overcoming the difficulties of the hill.

There were also many other remarkable performances which are on record. One was reported to have done the journey between London and Southampton, in some places, "at the rate of thirty-two to thirty-five miles an hour," the owner claiming that he could easily maintain an average of ten miles an hour. The actual results obtained often differed, however, very considerably from those reported to have been secured. Thus, while the public received a very glowing account of the journey of one of these uncouth monsters, a private letter from a "village blacksmith," through whose district the coach passed, gives the following depressing account of the performance.

He writes under date, Hurley, December 4, 1832: "We were apprised at midday, yesterday, that a steam coach was on its way to pass by our house. Of course we were all on the look-out. For my part, I thought it the greatest treat I could have. When, lo! about half past two o'clock, a great unwieldy monster arrived, in a most terribly crippled state, and stopped at our shop to be repaired. They brought their own mechanics with them, so that I had no trouble with it. When done, they made a very bungling set-out—stopping every twenty yards. I never was so disappointed in my life. They entirely emptied our well in filling their boiler, and we had forty men in the shop to witness the proceeding. As to the men, they were as black as devils; I should think the Londoners would quite laugh at them. If this be a specimen of steam coaches, I have quite done with them. They only came from Dorchester, and I believe reached Salthill, about twenty-eight miles, from morning to dark night, which I should have thought ought to have been done at two hours at furthest." Apart from the ordinary difficulties to be overcome, the drivers of steam carriages had also to face the obstacles placed in their road by hostile landowners or coach proprietors. In some parts tolls of 2*l.* were charged for a steam carriage, while a four-horse stage coach was let off with only 2*s.*, and this is not proving sufficient to drive the obnoxious engine off the road, a layer of loose gravel, a foot in depth, was laid down. Remembering the intense annoyance with traction engines now cause in agricultural districts, it is a matter for congratulation that this steam carriage craze soon died out without having obtained any hold on public favor.

In designing the carriages for the early railways, the coach was the type naturally selected, and on some out of the way branches old stock can still be seen built on these lines. In many cases each carriage had a distinct name, and a story is told of the consternation of the officials on a Northern railway, who found that they had unintentionally placed the Waterloo carriage at the disposal of a French general during his visit to the district. The second-class carriages, subsequently introduced, were, in regard to comfort, but little better than the thirds. They were open throughout at the sides. There was no glazing, and the partitions above the level of the doors, dividing the carriage into six compartments, each made to seat twelve persons, were formed of laths interlaced, and admitting free currents of wind. The clear length of each narrow gauge compartment was only 8 feet 7½ inches, and the width 4 feet 4½ inches, each seat being 15 inches in width. Stout passengers had some difficulty in squeezing through the doors, which were only 18 inches wide. The first glazed and inclosed second-class carriage that ran upon a railway was attached to the first express train that ran between London and Exeter, when the journey was made in five hours. In those days the passengers for the various intermediate stations were put into separate compartments, and the doors locked. This locking of doors was strongly objected to, and Sydney Smith wrote some scathing letters to the *Morning Chronicle* on the subject. In one of these he protests that the companies would never give up the pernicious habit until it had caused the death of a bishop; "even Sodor and Man will do."

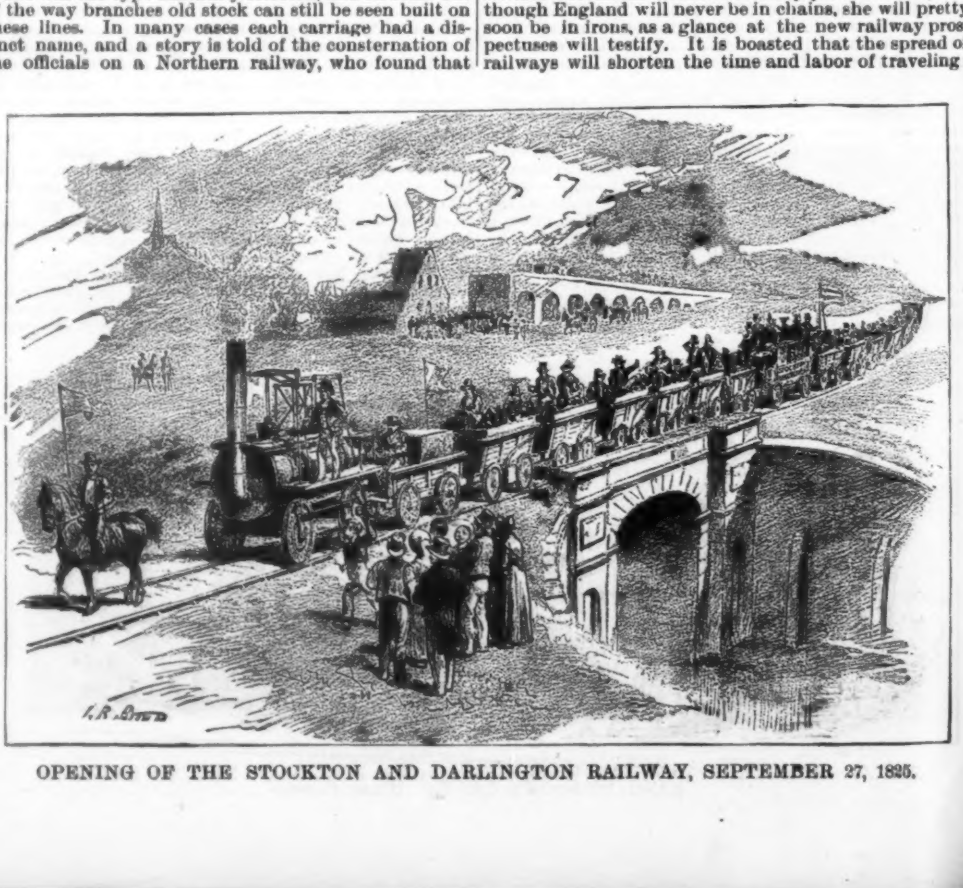
The guards, who were often dressed in scarlet like the old coach guards, were perched up in seats at the front and back of the trains, and the passenger's luggage was placed on the roof of the carriage in which he had taken his seat. The directions for passengers on the time bills of those days read, indeed, quaintly. For instance, "Passengers intending to join the trains at any of the stopping places are desired to be in good time, as the train will leave each station as soon as ready, without reference to the time stated in the tables, the main object being to perform the whole journey as expeditiously as possible. Passengers will be booked only conditionally upon there being room on the arrival of the trains, and they will have the preference of seats in the order in which they are booked. Each passenger's ticket is numbered to correspond with the seat taken. All persons are requested to enter and alight *invariably on the left side*, as the only certain means of preventing accidents from trains passing in an opposite direction." The fortunate proprietors of carriages could for an additional fare enjoy the privilege of riding in them with coachman and footman on the box. The welfare of servants was further provided for under a regulation which stated that "The first compartment of the leading carriage in first-class trains is reserved for men servants, and the second for women servants, in attendance upon their employers, at second-class fares."

When once the immense advantages and capabilities of railways were fully realized, the public, as every one knows, rushed from extreme distrust to the wildest confidence. Not only were railways to bring universal peace and happiness, but they were to make every one's fortune. Every one was infected with the mania, and all who could scrape together sufficient savings invested in one or other of the innumerable "Grand Junction" or "Direct Line" schemes which were brought forward.

Pages could be filled with the events of this extraordinary period, but no better idea can be formed of the extent and character of the mania of 1845–46 than from a study of the pictures in the volumes of the period of the greatest of modern historians—*Mr. Punch.*

On page 10745, for example, is his prophecy in 1846 of what a railway map of England would be like "in another year or two." Had he written in 1888, the prophecy would have been about fulfilled by this year's map in "Bradshaw."

Referring to this map, *Mr. Punch* said: "We are not among those who like going on with the march of intellect at the old jog-trot pace, for we rather prefer running on before to loitering by the side, and we have consequently taken a few strides in advance with geography, by furnishing a map of England as it will be in another year or two. Our country will of course never be in chains, for there would be such a general bubbling up of heart's blood and such a bounding of British bosoms as would effectually prevent that; but though England will never be in chains, she will pretty soon be in irons, as a glance at the new railway prospectuses will testify. It is boasted that the spread of railways will shorten the time and labor of traveling;



OPENING OF THE STOCKTON AND DARLINGTON RAILWAY, SEPTEMBER 27, 1825.

but we shall soon be unable to go anywhere without crossing the line—which once used to be considered a very formidable undertaking. We can only say that we ought to be going on very smoothly, considering that our country is being regularly ironed from one end of it to the other."

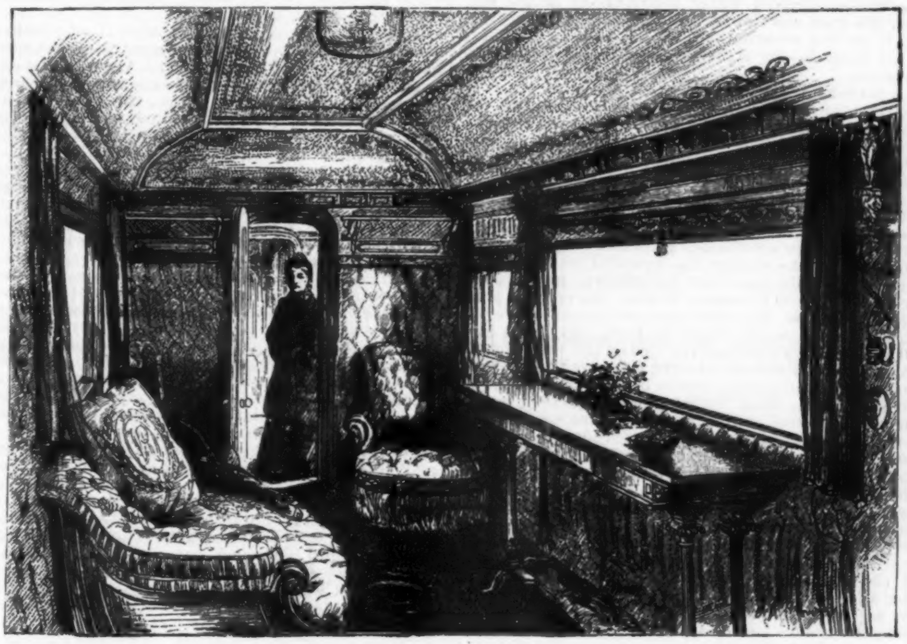
The center of all this vast speculation was George Hudson, the "Railway King," who for a brief period was the most popular and prominent personage in England, and a few years later the most hated and abused. He began life as a linendraper in York, but was lucky enough to acquire the friendship of an old man in that city, who, neglecting his kindred, bequeathed his money to Hudson.

Freed from the anxieties of trade, he became a violent politician, took an active part in municipal affairs, and was twice Lord Mayor of York.

While holding that office he gave splendid entertainments, and gathered round him peers, baronets, and squires. In 1836 he became interested in the York and North Midland Railway, was appointed chairman, and allied himself to George Stephenson in his coal mine ventures. From that time he devoted himself to railway work, and by his zeal and energy secured the utmost confidence, not only of those interested in the companies with which he was connected, but ultimately of the public at large. If it was known that George Hudson was connected with a new line, the shares were instantly applied for many times over, and large sums were often paid for the mere chance of an allotment.

His receptions were attended by the nobility and leaders of fashion, and his interest was as eagerly sought as that of a Prime Minister or Lord Chancellor. His manners were genial, but his comparative lack of education often placed him at a disadvantage in this exalted society, and many stories were told at his expense.

On one occasion, after dinner had been kept waiting some time, he explained to the hungry guests that he was waiting for a Mr. ——, and added, "He is my wife's *prima donna*," at which a titter went round.



THE QUEEN'S SALOON CARRIAGE IN A TRAIN OF TO-DAY.

"Don't mind George," said Mrs. Hudson to a gentleman near her, "he doesn't understand Latin."

On page 10745 *Mr. Punch's* artist gives a sketch of one of "King Hudson's Levees."

With such dazzling success and enormous power, it is not surprising that George Hudson's head was almost "turned," and that in the rush and hurry of his vast work he did things of a questionable nature. When, however, the panic came, the public could make no allowances, and he was then as bitterly assailed as he had a few months before been flattered. Time has, however, softened the harsh judgments passed in those days of loss and panic, and Sir Frederick Pollock, in his recent "Remembrances," says, "Hudson was more sinned against than sinning, and he bore himself, on the whole, fairly well among the temptations of an unprecedented kind which surrounded him." Speaking in the House of Commons a few weeks back, Mr. Gladstone also bore similar testimony to the harshness of the judgment passed on the fallen "Railway King."

Among other curious inventions which arose out of the success of the locomotive may be mentioned a contrivance called the cyclopede, for utilizing horse power in the manner indicated on page 10745. It is certainly not suggestive of a very rapid or entertaining form of locomotion. Balloons were also to be harnessed to the trains instead of locomotives.

In this short sketch of the "Early Days of Railways," we have dealt with social, rather than engineering, features, but our engraving of Chat Moss, copied from a rare print published shortly after the opening of the Liverpool and Manchester Railway, suggests the indomitable pluck and perseverance of Stephenson and other pioneers of railway enterprise, in overcoming difficulties regarded as insurmountable by the public. The construction of a railway across Chat Moss—which Dr. Smiles, in his interesting "Life of George Stephenson," describes as "a vast mass of spongy vegetable pulp"—was certainly a feat of which not only engineers and railway men, but the entire nation, may be proud. This "Moss" was of so treacherous a character, it was impossible to build a railroad across it on ordinary principles, and the scheme would have been abandoned but for Stephenson's idea of floating the line on its surface. This plan succeeded perfectly, and the section of line across Chat Moss affords some of the easiest running in the country.

In the above sketches, we have shown what sort of accommodation railway travelers had to put up with fifty years ago; with the comforts and luxuries of most modern carriages our readers are familar. In America, where the journeys are so much longer than in this country, even greater luxuries are demanded, and some of the great railway magnates have private cars fitted up in the most extravagant manner. The Great Western Company have, however, built a royal carriage which can challenge comparison the world over. Our artist gives a glimpse of its interior, but the sketch cannot, of course, convey a fair idea of the delicate coloring and design, which are worthy of the high duties the carriage has to perform.

[Continued from SUPPLEMENT, No. 672, page 10734.]

THE PLANT OF THE BOSTON HEATING COMPANY.*

By A. V. ABBOT, Chief Engineer of the National Superheated Water Company, of New York.

THE conditions which surround a pipe in the street are so different from those to which boilers are subjected, that a little consideration will show an explosion of the pipe to be an impossibility. A boiler, with its setting of masonry and bed of incandescent coal, is encompassed with a highly heated atmosphere which constantly tends to supply it with more and more heat.

The street pipe, on the other hand, *is hotter* than its surroundings. On the occurrence of a slight rupture in the shell of a boiler, the pressure is relieved from the large mass of water therein contained, and an outflow of the boiler contents established through the incipient opening.

The large diameter of the boiler shell permits the molecules of water flowing toward the incipient rupture to attain, before reaching it, a very high velocity; while the hot masonry surroundings, and especially the glowing coals and incandescent gases of the furnaces, furnish to the water continuous supplies of heat, maintaining the pressure and accelerating the rushing molecules. So, in far less time than it has taken to describe this action, the current of steam and water has attained such velocity that its impact has been sufficient to rend the boiler, and, perhaps overthrowing the masonry, hurl it hundreds of feet from its original location. In the street pipe, the comparatively small diameter precludes the possibility of a high velocity in the water current, even should an opening occur. Furthermore, as no supply of heat is furnished to the water, the pipe being surrounded by the comparatively cold conduit, every unit of steam formed abstracts and renders latent the heat from five units of water. Thus even if a rupture occurred in the pipe, no disastrous explosive action would follow, a simple tear through which the water would slowly escape into the conduit being the only result.

Before passing to the house connections between the main and the buildings, allow me to call your attention to the special screw thread which we have used in making the joints in the streets, with the twofold object of securing extra strength and greater tightness.

Ordinarily, a screw thread, as is well known, reduces the strength of the pipe or rod on which it is cut about 30 per cent. In Fig. 9 the special thread used in our plant is exemplified. The coupling joining the ends of the pipes, B and C, is made considerably longer than is customary in ordinary pipe fittings. For a little way the end of the coupling is bored out, so as to be a fairly accurate fit on the end of the pipe. This greatly improves the joint, as the overlapping end of the coupling tends to strengthen and support the pipe that is introduced into it.

The special peculiarity of the thread to which I wish to call your attention, however, is that portion between the points b b' and c c'. It will be seen that the top of the thread is in a straight line with the outside of the pipe, while the bottom of the thread, between the points, b b' and c c', is inclined to the axis of the pipe at a considerable angle, so as to cause it to run out or vanish at b' or c'. By this means the weakening of the pipe caused by the cutting of the thread is spread out and diffused over a considerable length; and, by proportioning this vanishing of the thread in a proper manner, experiment has shown that it has been possible to preserve ninety-seven per cent. of the full strength of the pipe. In addition, this vanishing of the thread produces a long and very tapering cone, which may be forced into the coupling by means of the pipe tongs in such a way as to actually bed the metal of the pipe into that of the surrounding coupling and make a joint which is absolutely tight. This same result is attained in a less degree with the ordinary pipe thread, but, inasmuch as the cone produced by our special thread is very much smaller angle than that used by standard pipe fittings, the pressure of the tongs in making up the joint causes it to bed more firmly into the metal of the coupling. The rolling mill supplies pipe in lengths of about twenty feet, so that the necessity of securing a perfectly tight connection between each length is very apparent. With this form of thread our experience has demonstrated that, even under 1,500 pounds, it is perfectly possible to secure absolutely tight joints. In testing the sections, we have never found a leak when the joints were properly made.

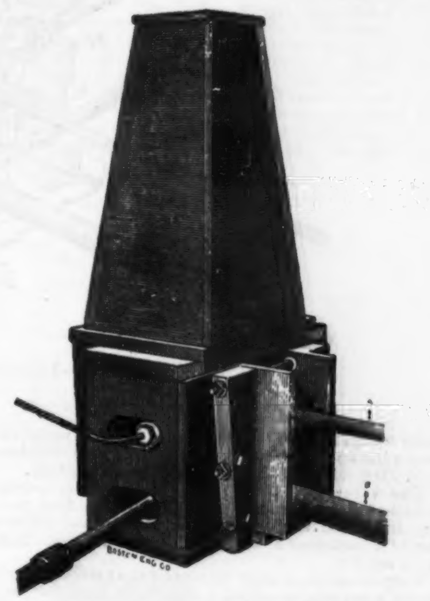


FIG. 10.—SERVICE BOX.

Each coupling also forms an opportunity for a house connection. On either side of the coupling a boss is cast. For the house supply inch pipe is used, and for the return two-inch pipe, which extends from the main to the sidewalk on either side of the street, passing through a box made of creosoted yellow pine. At the sidewalk a service box (shown in elevation in Fig. 10 and section Fig. 11) is situated. In Fig. 10 the supply pipe may be seen at A, while the return pipe is indicated at B. These pipes, A and B, enter the box, and there terminate in a three-way tee provided with asbestos cocks, by means of which the supply from either branch of the tee can be at pleasure controlled.

By means of this three-way tee and its asbestos cocks, each service box is enabled to supply three houses. From the service box to the inside of the house wall—usually a distance of not more than eight feet—copper pipe is employed in preference to iron pipe. The advantage of copper pipe in this location is very obvious when it is considered that, owing to the ductility of this metal, the pipe can be bent in any desired shape without the necessity of special fittings, involving the construction and maintenance of a large number of joints. So, by using, from the service box to the inside of the house wall, a copper pipe, we are enabled to in-

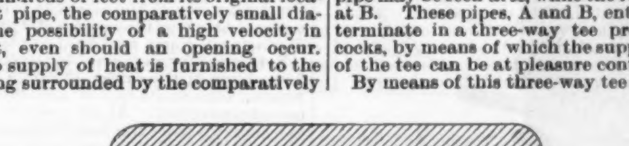


FIG. 9.—SPECIAL THREAD.

* Read before the Boston Society of Civil Engineers, November 16, 1887. From the *Journal* of the Association of Engineering Societies.

troduce in it as many bends and carry it around as many corners as may be necessary.

The size of copper pipe which we most frequently used is quarter inch, which is amply sufficient to supply ordinary buildings. In the case of large stores or warehouses, three-eighths or one-half inch is employed; while, where it is desired to supply power to an engine of 25 or more horse power, five-eighths or three-quarter inch pipe is employed. A one-inch pipe, such as you see here, would be ample to supply so large a building as the post office. All of these samples of copper pipe which you see here have been tested to over 6,000 pounds. The sample of one-inch pipe split at 6,200 pounds, while the smaller size held 7,000 without showing any signs of failure.

The water, as I have already shown, is merely the vehicle for the transportation of heat. And now having indicated the method by which we introduce it inside a customer's wall, the question arises, How can it be used?

Very broadly, it may be stated that our service is perfectly adequate to afford a supply of heat for any purpose whatsoever requiring a temperature of 400 degrees or less, whether it be for heating, power, cooking, chemical operations, or any branch of manufacturing. The various appliances, however, by means of which the heat contained in the water may be utilized are as varied as the different branches to which it may be applied.

For heating simply two plans present themselves. Hot water can be introduced directly into a radiator, which may occupy the same position that the present furnace in the house takes up, and may warm a quantity of cold air supplied through the cold air box, and send that air heated through the flues that are already in place, so as to warm the building in the same way that the furnace does at the present time, only substituting a hot water coil for the glowing mass of incandescent coal

Where the edifice is already piped for steam, or in case of a set of offices where a very varied supply is desired, steam heating in the usual manner may be resorted to by the introduction of a device called a "converter." This contrivance, shown in Fig. 12, may be very briefly described as a steam dome, for in reality in our system it occupies the same place that a steam dome does in a boiler. If, in imagination, you will conceive an ordinary boiler to be stretched out so as to occupy two miles of space, you will have a very fair conception of our system as applied to the distribution of steam heat.

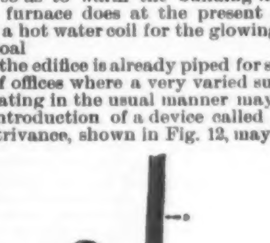


FIG. 12.—THE CONVERTER.

The end of the copper pipe, A, as it comes in from the street is attached to a reducing valve, B. This reducing valve we make of rather peculiar construction, so as to specially adapt it to withstand the pressure to which it is subjected and also to afford a regulator of unusual sensitiveness and durability. By means of the pressure-reducing valve, most of the pressure on the water contained in the copper pipe is removed and the water allowed to flow into a large iron receptacle, C, which forms the steam dome proper. By the removal of the pressure a part of the water is thereby permitted to take up the superfluous heat and to expand into steam.

On the left-hand side of the converter a small steam gauge is shown, the purpose of which is to constantly record the pressure to which the converter is subjected, and to enable the reducing valve to be set so as to give a pressure of any desired amount. In the top of the converter a steam pipe, B, conveys the steam away as fast as it is formed, and carries it to any part of the building where its use may be desired. At the bottom of the converter a return pipe, E, may be seen connected to a float trap placed on the inside of the converter. Another pipe, F, is used to convey back to the converter the condensed water from all of the radiators, so that there may be little or no loss in the system. As fast as this condensed water accumulates in the converter, the trap previously alluded to discharges the water from the return main, E, and allows it to flow into the main in the street, whence it is conducted to the station.

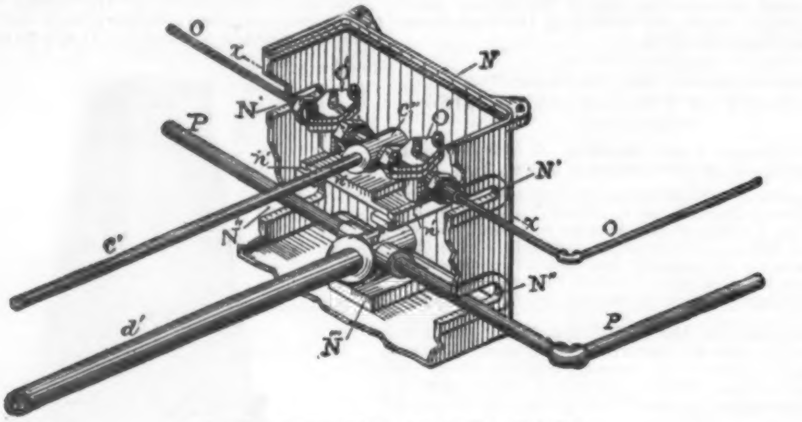


FIG. 11.—INTERIOR OF SERVICE BOX.

As a precautionary measure, a safety valve, G, is attached to the converter, so that in case of any failure of the reducing valve to act in a proper manner, which might possibly allow a greater pressure to come on the converter than is intended, this safety valve will open and permit the contents of the converter to flow into the return main, and relieve itself entirely.

For supplying steam to an engine no change is made in the converter excepting to enlarge it sufficiently so that there may be a sufficient quantity of steam always on hand ready to supply the cylinder of the engine. We generally calculate that, to preserve an adequate supply, it would be necessary to have the volume of the converter at least ten times that of the cylinder of the engine which it is designed to feed. So, for a large engine, we merely increase the size of the iron dome to such proportions as shall always preserve the requisite amount. For any cases where both heat and power are desired in the same building, as frequently occurs, we use a compound converter with two reducing valves so arranged that the water first introduced from the street shall expand into one chamber, giving, for example, a pressure of 60 pounds of steam for the purpose of driving an engine. As soon as the water, under the pressure of 60 pounds, is discharged from this first chamber in the converter, by means of the trap, it is received in a second one, where, by means of an additional reducing valve, the pressure is again reduced and the remaining portion of heat contained in the water allowed to expand a part of it into steam, which may be used for heating. By this means we are enabled to reduce the temperature of the water to the greatest amount, thereby returning it to the station as cool as possible.

In a system of this kind protection from radiation is an exceedingly important consideration. After a number of exhaustive experiments on nearly all of the non-conducting coverings now in use, we decided to adopt a covering made of asbestos. The covering is simply a role of pure asbestos fiber 1½ in. thick. It is made by taking the asbestos from the mines, carding it in the same way that cotton wool is carded, and winding it around a cylindrical roll. After the mixture is dry a saw is run along the side of the roll, cutting the covering in two; then the roll is opened, and it is taken off. On the outside of the asbestos is a solidly woven cloth made of asbestos rendered waterproof by an admixture of plaster of Paris, and held in place by wire netting.

Returning for a moment to the section of conduit, Fig. 5, we have in the center the pipe itself; outside of the pipe an inch and a half of asbestos with a water-proof asbestos covering. An air space of four inches separates the asbestos from the first brick arch, then a second air space of 2 in. and a second brick arch. So we think the system is about as thoroughly protected from radiation as could be done. As to the insulating power of the asbestos, this experiment may be interesting:

I had an air bath made, so arranged that it could be kept at a constant temperature of 500 deg. Fahr. A sheet of the asbestos covering, just as you see it, was laid on top of the air bath. In contact with the upper side of the asbestos a piece of 2 in. yellow pine plank was placed so as to cover the sheet entirely. Between the asbestos and the plank a second registering thermometer was introduced, so that the temperature between the asbestos and the plank could be accurately ascertained. The experiment was continued for several days, during which time the air bath was constantly maintained at a temperature of 500 degrees, and the highest temperature ascertained as occurring between the asbestos and the wood was 158.

The relative cost of transporting heat from point to point is a most important consideration. Suppose that it is wished to maintain at any place a constant temperature. It may be a radiator for steam heating or a cook stove or steam engine. If we have a vessel in which we wish to maintain a constant temperature, it is necessary to supply the heating medium to that vessel at a higher temperature than that at which it is to be sustained, and the greatest economy of maintenance is only achieved by supplying the medium to the vessel at the highest possible temperature and exhausting it therefrom at the lowest; in other words, to furnish the least quantity of the circulating medium with the greatest possible fall in the temperature. If we supply a pound of water, we will say at 400 deg., and let it cool down to 200, we get 200 units of heat; if we supply it at 300 and allow it to cool down to 200, we get only 100 units of heat. So that in the practical operation of a system of this kind, the aim should be to introduce the circulating medium at the highest temperature and reduce it to the lowest. The temperature required for cooking is about 350 deg., and it is probable that this demand is the most severe that can be made on the system; and for a discussion of the relative advantages of water over steam as a medium for the transmission of heat, I have selected this as being the one that would present the system in its worst light.

If a range is to be maintained at a temperature of 350 deg., it is proposed to supply water at 400 degrees. Suppose there is introduced into the range a cubic foot of water at 400 degrees. The weight of the cubic foot of water is 53·63 pounds. If the temperature of the range is to be kept at 350 deg., the water can only be allowed to fall 350 deg. The fall in temperature is, therefore, 50 deg. The whole quantity of heat liberated by the fall of the water is 53·63 times 50 times 1·0174, or 2,728 ($53·63 \times 50 \times 1·0174 = 2728$) heat units.

The medium which is most commonly used instead of water for the transmission of heat is steam. Supposing, instead of admitting to the vessel a cubic foot of water, we admit therein a cubic foot of steam at the same temperature of 400 deg. That cubic foot of steam weighs 0·547 pound. Now, if that steam falls from 400 to 350, a portion of the steam is condensed and the latent heat liberated. A cubic foot of steam at 400 deg. weighs 0·547 pound, and at 350 degrees it weighs 0·3056 pound. The difference between the two is 0·24 pound.

The latent heat of evaporation of steam at 400 deg. is about 830 units per pound, therefore by multiplying 830 by 0·24 we obtain a product of 199·2 as the number of heat units set free by the fall in temperature of a cubic foot of steam from 400 to 350 deg. It has been seen that the cubic foot of water will deliver 2,728 units of heat, while the cubic foot of steam yields 199. The ratio of these two quantities is 1 to 13·7.

Hence it is obvious that 13·7 cubic ft. of steam must be circulated to do the same amount of heating as may be accomplished by 1 cubic ft. of water. Just as soon as the steam has fallen to the temperature at which it is required to maintain the range, the steam must then be exhausted to give rise to a new supply. It is true that steam, being a light, aeriform fluid, will flow through pipes more easily than water will.

By the well known laws of hydraulics, the relative velocities at which fluids travel through pipes vary inversely as the square root of the densities. The relative density of water to steam is as 1 to 9·87. Consequently, under the same conditions, with the same length of pipe, the same resistances in the pipe, and the same pressure on the circulating medium, 9·87 cubic ft. of steam would flow to 1 ft. of water. But the water is to the steam, as far as heat-carrying power is concerned, as 1 is to 13·57; whereas the relative quantities which would be transmitted through a pipe are as 1 to 9·87. The expense of delivering to a distant point any fluid depends simply upon the amount of mechanical work necessary to overcome the resistance of the pipe. The relative velocities at which water or steam will flow are as 1 to 9·87; but the relative quantities necessary to deliver the same quantity of heat are as 1 to 13·7, hence the current of steam must have a velocity of 0·135 time that necessary for the water current. Remember that the transmission through a pipe is not a question of weight, but a question of volumes. A 4 in. pipe will carry no more cubic feet of mercury than it will of hydrogen gas, although the density of the mercury is several thousand times that of the hydrogen. It will carry more pounds of mercury, but no more cubic feet. So to deliver equal quantities of heat there must be in the case of steam a velocity of about 0·135 time that of the water. The mechanical work, which is the measure of the expense of transportation of a fluid, varies as the cube of the velocities at which the fluid flows. We have seen that under similar circumstances, if the velocity of the water current is 1, the velocity of the steam current to transmit an equal amount of heat must be 1 and 35. Cubing, it is obvious that the relative expense of transporting equal quantities of heat by steam or water will be as 1 to 2½.

It is usually assumed that a current of steam flowing through a pipe is maintained by the expansive force in steam inself. Precisely; but this expansive force in the steam is only attained by a fall in pressure and temperature, and consequently by a corresponding amount of condensation.

Returning to our former example, if, at the end of a long line of pipe, it is wished to deliver steam at a temperature of 400 deg., corresponding to a pressure of 250 pounds to the square inch, it would be necessary at the central station to put upon the boilers a sufficient pressure in addition to that at which it is expected to deliver steam to overcome the inevitable friction of the pipe between the boilers and the place where the steam is to be received. In a long line this friction is of considerable amount, so that, in order to accomplish the necessary delivery of steam, the boilers would be called upon to bear a burden equal to the amount of radiation of the line plus the amount of frictional resistance offered to the steam current. The frictional resistance may of course be reduced to a minimum by the use, in line, of pipes of very large diameter. This has frequently been done, with the inevitable result of very largely enhancing the cost of the plant and increasing the difficulties both of construction and maintenance.

In the case of the water plant, it is only necessary to subject the boilers to the pressure requisite to give the temperature at which it is wished to deliver the water plus the much smaller amount of radiation which takes place from a pipe of less diameter than that employed in the steam plant, the frictional resistance of the pipe being entirely overcome by means of the forced circulation obtained by the pump. The boilers, which perhaps are the most difficult part of the system, being entirely relieved from this extra pressure, are much more easily constructed and maintained. Thus by means of the use of an incompressible fluid like water, and the employment of a pump to produce circulation, a much higher initial pressure can be placed upon the

pipe line to overcome the frictional resistances of the pipe, thus enabling us to employ a very much smaller pipe than is customary to use in steam plants, and largely decreases the expense of the system and the difficulties of construction and maintenance.

Even to engineers too much mathematics is provocative of a certain kind of madness, which I am fearful my insipid figures may have already induced. Alas! that I have not the brush of an artist or the tongue of an orator to adequately depict for you the future which we believe will grow from the germ that last summer, 'mid trouble, confusion, and annoyance, we planted in the subsoil of the Boston streets.

We dream of a tropical future from which dust, ashes and smoke are banished: of chimneyless houses, from the cellars of which the black diamonds of the present are exiled, giving place to paper and paint, and be coming habitable.

We dream of matrons made happy by the absence of dust, on whose carpets no particle of ashes ever lights; and yet whose houses are as balmy as the air of the tropics; whose range is never cold; whose ovens never refuse to bake; nor is the good man's wrath ever provoked by the tardy breakfast, the fault of the oversleeping domestic; for, lo! in an instant, by a touch on a valve, the range glows with heat, and winter or summer, early or late, the ovens, at a constant and equable temperature, never refuse to fulfill their duty on the minute.

Who knows! Ten years ago, when the first squeaky voice pulsated across Machinery Hall, Boston little dreamed that now it could talk to Chicago. In comparison with the electrical wonders of the past decade, our most sanguine expectations seem easy of realization; and when achieved, Boston may again take to herself the credit, as she has often done in the past, of being the successful pioneer in a new field.

FEBRUARY 10, 1888.

POSTSCRIPT.—The main and station of the Boston Heating Company was completed and in readiness to commence circulation about the middle of December. The pipe line, after being tested from the station round to the station again, was thoroughly washed out to remove all dirt and grease, by pumping water through it for two days. The main was then connected with a battery of boilers of 200 horse power, underneath which a slow wood fire was started, so as to gradually heat the water contained in the boilers. A steady circulation was at the same time maintained through the whole of the main, so that as fast as the water was warmed in the boilers, it might be sent out into the main, thus gradually heating the whole system.

About ten days was consumed in warming the main up to the temperature of about 380 deg. During this time the whole line was carefully watched to ascertain whether any leakage developed, and whether the expansion joints worked in a proper manner. No trouble of any kind was experienced, the main under heat being found to be fully as tight as it was under cold water pressure. All of the expansion joints operated as had been anticipated, taking up the expansion, as the temperature increased, in a perfectly satisfactory manner. After the temperature of 380 deg. was attained, a solution of potash was pumped into the mains and circulated for several days in order to remove all grease and red lead, so that the system would be full of clean water. After two or three days' circulation of potash water, the main was cleaned by allowing the hot potash water to escape, and replacing it in the boiler with fresh warm water. This cleansing of the main was continued until the water showed no signs of potash or grease.

After this thorough cleansing had taken place, the various consumers, whose house connections had been made, were, one after another, turned on to the line, and at the present time the company is heating about twenty-five large buildings and supplying power to some engines.

So far all the consumers on the line have expressed complete satisfaction with the service rendered to them. Experiments on the losses by radiation show that the steam furnished is exceptionally dry. One engine is run from an exposed pipe over 60 ft. from the converter, and no trouble whatsoever is experienced with water in the cylinder, showing that even when the steam is exposed to this amount of radiation, it is as dry as steam furnished by ordinary boilers.

LIQUID FUEL ON LOCOMOTIVES.

IN view of the rapid development which is taking place in the various branches of the petroleum industries, and the transport facilities which are being afforded by the building of tank steamers, etc., very considerable interest attaches to the mode of employing liquid fuel on locomotives now being carried out by Mr. James Holden, the locomotive superintendent of the Great Eastern Railway. That locomotives can be worked—and most successfully worked—by the use of liquid fuel alone has been amply demonstrated by the experience of Mr. Thomas Urquhart, on the Grazi-Tsaritsin Railway in South Russia, and by the experiments on the Pennsylvania Railway, where Mr. Urquhart's system has been thoroughly tested. But the conditions existing in South Russia are eminently different to those existing in this country, and in the present state of our liquid fuel supply, and the irregularities in the market which—probably for some little time to come—would be produced by any abnormal demand, grave difficulties exist in the employment of such fuel on any English railway in the exclusive manner in which it is so successfully used by Mr. Urquhart.

These and other practical difficulties have been thoroughly appreciated by Mr. Holden, who has met them in a thoroughly common sense way. In place of altering any of his engines to liquid fuel burners exclusively, he has been contented—for the present at all events—to use the liquid fuel as an auxiliary to, and not as an entire substitute for, coal; and while making provision for replacing a large proportion of coal by liquid fuel, he has left the engines fitted with his apparatus fully available at any moment to work with coal alone if desired. In fact, the change from using coal and liquid fuel in combination to coal alone can be—and has been—made in the middle of a run without inconvenience.

The arrangements which he has devised for burning the liquid fuel are very simple, and will be readily understood from the annexed engravings. From these it will be seen that the ordinary firegrate and firebrick arch are left unaltered, the only alteration in the firebox being the insertion of a couple of tubes about 6 in. in diameter through the rear water space, one on each side below the level of the firedoor, as shown in Figs. 1, 2, and 3. To each of these tubes is fitted a liquid fuel injector combined with a ring jet for inducing a current of air. A perspective view of one of Mr. Holden's injectors is given in Fig. 4, while Fig. 5 is a section. The best proportions for these injectors and the best disposition of the accompanying ring jet have of course been arrived at after a considerable amount of experimenting, but the arrangement itself is extremely simple, and answers its purpose admirably. The steam is supplied to the central jet of the injector, on issuing from which it meets the annular stream of liquid fuel which is supplied to the injector through the branch shown, the mixed steam and spray being discharged through several openings in the flattened nozzle (see Fig. 4). The steam is supplied direct from the boiler without any superheating.

The ring jet surrounds the front part of the injector as shown; by its means a strong induced current of air is formed and directed upon the issuing jet One cock regulates the steam supply to both injectors; this cock together with two others controlling the ring jets and another which is used as a warming cock when necessary for heating the liquid fuel in the tank, being neatly combined in one fitting, mounted on the back of the firebox, and connected by an internal pipe to the dome. The warming pipe above mentioned is only used in very cold weather when burning tar or very heavy oils. The liquid fuel flows to the injectors by gravity, the tank containing it being sufficiently elevated: the supply is regulated by a separate cock to each injector. Provision is also made for blowing steam through all the oil pipes, etc., and, in fact, the whole of the arrangements are worked out in a thoroughly practical way.

In working on Mr. Holden's system, a thin coal fire is kept on the grate, and to assist in keeping the grate properly covered with a very thin fire, lumps of chalk are placed on the grate when starting work for the day.

The ash pan dampers are kept very nearly closed, nearly the whole of the air required for supporting combustion entering either through the injector tubes or at the firedoor, which is kept open and fitted with an internal deflector, just as when coal alone is being burnt. It is found that when burning the liquid fuel an exceedingly soft blast is required, and the blast nozzle has to be materially larger than usual. Thus in the case of engine No. 193, of which we shall speak presently, and which has cylinders 17 in. in diameter by 24 in. stroke, the blast nozzle has been enlarged to 6 in. in diameter, while the smokebox has also been fitted with air valves by which air can be admitted near the base of the chimney and the exhaustion due to the blast thus diminished. To enable the engine to be used as a coal burner, if necessary, however, the blast pipe is fitted with a supplementary nozzle of the ordinary size, which, by means of an external lever, can be at once brought into position.

The first experiments of Mr. Holden on liquid fuel burning were made at the Stratford works of the Great Eastern Railway Company, on a boiler in the department where Pintsch's oil gas is manufactured for lighting trains. At these gas works one of the products is a tar which it is difficult to dispose of at any price, but this is now burnt under the boiler, which was fitted with the liquid fuel apparatus early in 1886. The boiler is a small one of the Cornish multitubular type, 10 ft. long by 4 ft. in diameter, with a furnace 7 ft. long by 3 ft. in diameter, from which 122 iron tubes 1¾ in. in diameter by 3 ft. long extend to the back of the boiler. The boiler is worked at 60 lb. pressure, and when coal was used the consumption per week (79 hours in steam) averaged 68 cwt. 1 qr. 16 lb., or 97·1 lb. per hour. With the liquid fuel apparatus the consumption per week, with 69 hours in steam, has averaged 454½ gallons of tar and 2 cwt. of coal, or an average per hour of 65·9 lb. of tar and 3·3 lb. of coal.

The arrangement was next applied to three boilers of the locomotive type in the wagon department at Stratford, and on these its performance has been very satisfactory. The boilers are worked at 80 lb. pressure, and the comparative results of a week's working with coal only and with coal and liquid fuel in combination have been as follows: With coal (Staveley) only, the consumption for 63½ hours' work, including lighting up, was 156 cwt., or 275·1 lb. per hour. With the coal and oil in combination, there were used in 60½ hours' work (including lighting up) 55 cwt. of Staveley coal and 546 gallons of green oil, or an average of 101·8 lb. of coal and 99·8 lb. of oil (= 9 gallons) per hour. With coal only, the evaporation was at the rate of 7·16 lb. of water per pound of coal, while with the coal and oil it was 8·91 lb. per pound of the combined fuels.

Subsequently the system was applied to a furnace in the steam hammer shop, a rivet furnace in the boiler shop, a Cornish boiler in the printing department, a six-coupled tank locomotive used for shunting purposes, and a four-coupled tank passenger locomotive (No. 193).

In the case of the printing office boiler just mentioned, the apparatus is fitted as shown in Figs. 6 and 7 an-

Fig. 1.

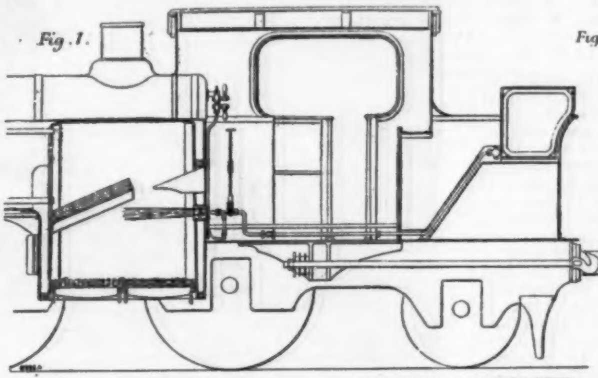


Fig. 2.

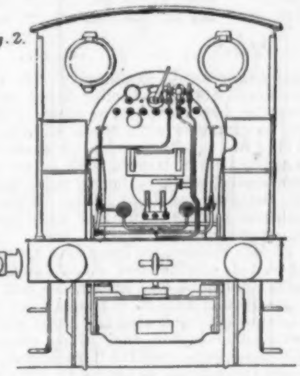
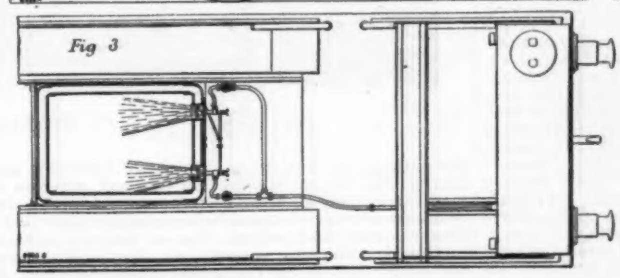


Fig. 3



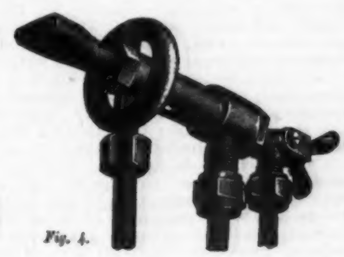
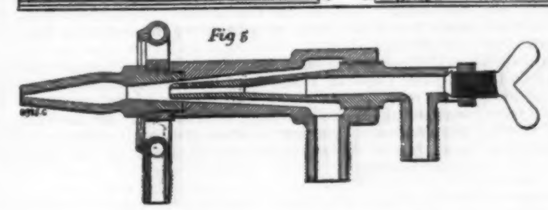


Fig. 4.

Fig. 5



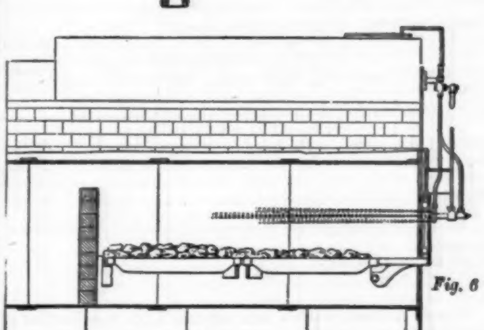
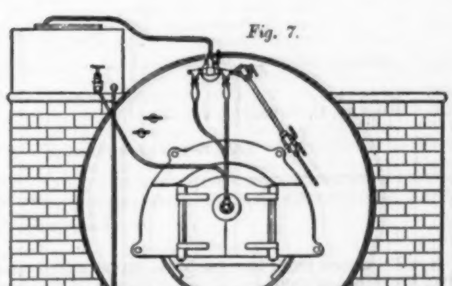


Fig. 6

Fig. 7.



LIQUID FUEL ON LOCOMOTIVES.

nexed, and a comparison of the cost of working with coal only in 1887, and with coal and liquid fuel during the present year (the comparison being made for a week in each case), gives the following results:

Coal only Used.

1887. Consumption during one week from August 15 to 20 (inclusive), 74¼ hours' work, including lighting up =80½ cwt. = 121·3 lb. per hour.

Cost for 100 hours = 12,180 lb. of coal at 11s. per ton =2*l.* 19s. 7½d.

Coal, Coke, and Tar—"Holden's System."

1888. Consumption during one week from June 25 to 30 (inclusive), 87¾ hours' working, including lighting up:

= coal 15 cwt.	= 19·2 lb. per hour	
=coke 11½ "	= 14·7 " " "	
Gas tar 280 gals.	= 35·1 " " "	
Total.........	69 " " "	

Cost for 100 hours:	s.	d.
= 1,920 lb. of coal at 11s. 0d. per ton =	9	5¼
= 1,470 " " coke at 9s. 6d. " " =	6	1½
= 3,510 " " tar at 12s. 6d. " " =	19	7¼
Total £1	15	2

The passenger tank locomotive No. 193, which we have mentioned above as being fitted with the liquid fuel apparatus, has, as we have already stated, cylinders 17 in. in diameter with 24 in. stroke, and coupled wheels 5 ft. 4 in. in diameter, and since it was fitted with the apparatus in March, 1887, it has been running most successfully, working heavy suburban trains of 15 carriages, making frequent stops, while it has also been employed taking main line passenger, averaging about 10 carriages, on longer runs. Through the courtesy of Mr. Holden we have had an opportunity of traveling on this engine, and we can testify to the ease with which the liquid fuel apparatus can be managed.

With the liquid fuel it is found that the steam is kept up more easily and steadily than when coal alone is used, while the liquid fuel gives especial facilities for getting up steam rapidly if required, the pressure being raised from 50 lb. to 140 lb. in nine minutes with the engine standing. Engine No. 193 is fitted with a liquid fuel tank containing 210 gallons, and this quantity will, as a rule, last for a run of about 200 miles, varying, of course, according to the weight and character of the train hauled. Various kinds of liquid fuel have been used, and the apparatus appears capable of dealing with any of the ordinary marketable qualities. On the occasion of our making a trip on the engine, there was being burnt a mixture of one-third "green" oil with two-thirds tar, and this was burnt entirely without smoke or trouble of any kind. Roughly speaking, the consumption of fuel on the engine above referred to is one gallon (or 11 lb.) of liquid fuel (a mixture of two-thirds ordinary gas tar and one-third creosote, or furnace oil) to about 14 lb. of coal per mile. We subjoin particulars of a comparative trial of this engine and a sister engine, No. 194, employed in working the same trains, No. 193 burning coal and liquid fuel in combination, and No. 194 coal only. "Radford" coal was used in both cases. The trial commenced July 12 and concluded July 20, 1888, each engine having worked six days. The following statement shows miles run, quantity and cost of fuel, etc., consumed by each engine during that period:

Engine. No.	Engine. Driver.	Total Miles Run.	Total Pounds Used. Coal.	Total Pounds Used. Liquid Fuel.	Total Pounds Used. Chalk.	Pounds per Mile. Coal.	Pounds per Mile. Liquid Fuel.	Pounds per Mile. Chalk.	Total pounds of Coal, Liquid Fuel and Chalk, per Mile.	Proportion of Liquid Fuel and Chalk to Coal Used.	Total Cost of Fuel.	Cost per Mile in Pence.
										Per cent.	£ s. d.	
193	Bryant, J.	951¾	18,511	10,505	784	14·2	11·0	0·8	26·0	83	9 1 5	2·28
194	Hughes, C.	951¾	27,738	....	......	29·1	......	...	29·1	....	9 4 10½	2·33
Difference in favor of No. 193 engine....											3 5½	0·05

N. B.—Cost of coal computed at 14s. 11d. per ton.
" liquid fuel computed at 1½d. per gallon of 11 lb.
" chalk computed at 5s. 6d. per ton.

It will be seen from the facts we have stated above that Mr. Holden's system of using liquid fuel is one of very great promise, and it appears to us of especial value for use in cases where it is of importance to be able to at once revert to burning coal alone, as may occur in consequence of fluctuations in the market price of oil or other circumstances. In the case of railways, for instance, it is an especial convenience that an engine fitted up for burning liquid fuel can at any time be run with coal alone in the event of its having to work in a district where a store of liquid fuel has not been established. In the case of war vessels also, the use of liquid fuel as an addition to coal appears to have many practical advantages not at present attendant on the use of liquid fuel alone. We believe it is intended to extend the application of the system on the Great Eastern Railway, and we hope in due course to be able to place before our readers a further account of the results obtained.—*Engineering.*

ICE CUTTING IN THE VALLEY OF JOUX.

ALTHOUGH natural ice has been employed from remote antiquity for cooling beverages, the use of it has not spread, and the exploitation of it has not been developed, because the industry and commerce have not had rapid and economical means of transportation at their disposal. The immense fields of ice that nature offers to human activity have remained unworked, while the artificial ice industry has assumed a great importance. But for the past few years the consumption of this product has rapidly extended, both for industrial and private uses, the markets have largely increased, and the exploitation of natural ice has been widely developed. It is chiefly in the United States that this increase has manifested itself, and that the consumption of ice, from a luxury, has become common and indispensable. The city of New York, alone, uses annually more than 700,000 tons of ice, and the consumption of it is ever increasing. The product is stored up in immense ice houses, of which, on the upper Hudson, more than 200 are met with that each contains from 50,000 to 60,000 tons. The annual exploitation in the United States yields more than 20,000,000 tons, 8,000,000 of which are exported to the Indies, to Africa, and even to Europe.

The consumption in France does not reach such proportions, although it is continually increasing. It is from Norway and Sweden principally that we get

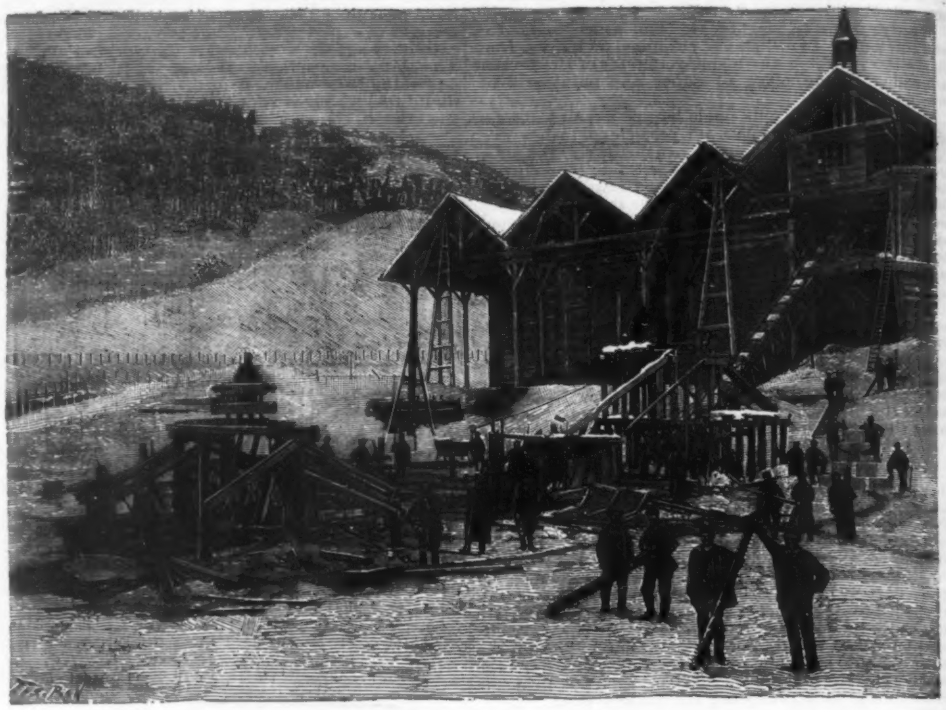


FIG. 1.—SAWING AND STORING ICE IN THE VALLEY OF JOUX.

the natural ice that we use. Norway sends it in huge blocks like dressed stones. Switzerland, wherein the exploitation has been hitherto paralyzed by the want of means of transportation, is beginning to give this industry a serious extension. One of the most interesting installations of that country is that of Mr. Lecoultre, established upon the border of the lakes of the valley of Joux, and of which we shall give a short description.

In France, our ice houses are principally subterranean, and the type of them has been but slightly modified. They are deep cellars, with a drain to carry off the water due to the melting of the ice. In America, on the contrary, the ice houses are built above ground, and this is the style to which those of the valley of Joux belong.

These houses, which are situated on the border of Lake Brenet, near the Pont railway station, consist of two large wooden buildings, 36 feet in height and nearly 68 million square yards in area, and rest upon a low masonry base. They are roofed with tiles, and are capable of holding 1,050,000 cubic feet of ice. Trusses spaced 16 feet apart rest upon wooden posts 36 feet in height. Boards nailed externally and internally to these uprights form a double envelope ten inches in width, which is filled in with sawdust—an insulating material which much diminishes the rapidity of the ice's melting. However, it is not in the ice house, but during transportation, that most of the melting takes place. The ice is exploited in quite a curious and very primitive way. When the point has been selected for cutting, a beginning is made by opening a channel between it and the ice house by means of handsaws operated by two men. The ice taken from this channel is first stored, and then, by means of the same saws, rectangular "rafts" are cut out and towed toward the buildings. On these pieces, bands of from 20 to 25 inches in width are marked off with an iron tool, and they are then passed under a small bridge. Upon this latter stand five or six men, who, by means of very heavy, pointed iron rods, smartly strike the ice along the successive marks in measure as they pass before them, and thus divide the mass into bands of equal length. These pieces then pass before men provided with hatchets, who cut them into nearly regular cakes, whose weight varies according to the thickness of the ice. It now only remains to store these in the ice house. This operation is effected by means of inclined planes analogous to those used in American ice houses, along with screw elevators. The elevator consists of an iron plate and angle iron frame, formed of two large girders 115 feet in length, strongly cross-braced, hinged at their upper part, and resting upon a movable bearing point, so that it can follow the variation in level of the water of the lake. Two chains follow the upper chord of each girder in rising, and the lower in descending. These, at intervals of three feet, are provided with hooks to which are fixed U-irons designed to seize one of the cakes of ice to be raised. These chains run over two hexagonal tumblers actuated by a 20 h. p. steam engine. The lower part of the frame enters the water, and all that has to be done is to push the cake of ice so that it shall be seized by the U-iron which is about to emerge from the water.

This very simple arrangement has permitted of raising as many as 35,000 cubic feet of ice per day of 12 hours, and of doing away with the force of 100 men formerly employed when slides were used. It will be still further improved by the installation of a device

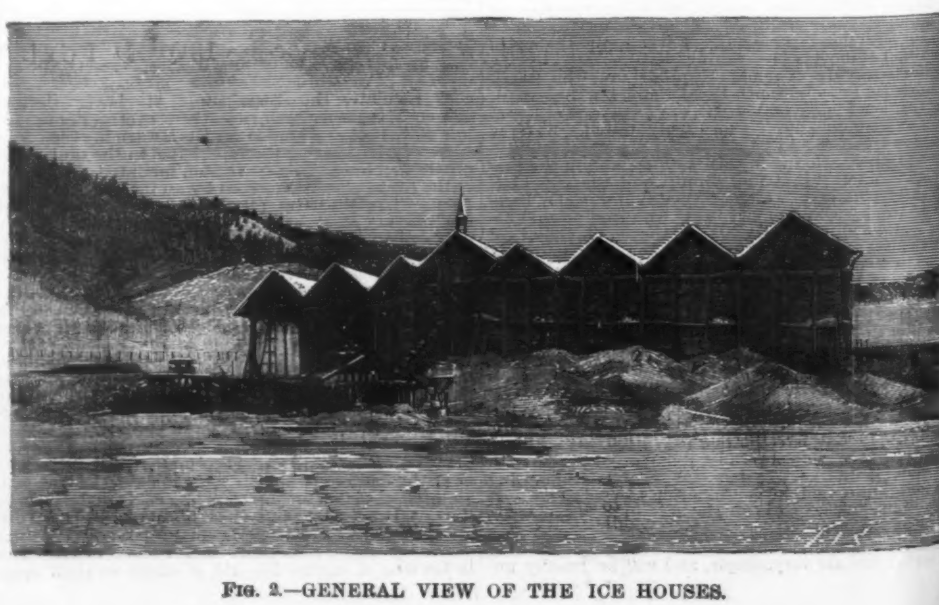


FIG. 2.—GENERAL VIEW OF THE ICE HOUSES.

that will permit of distributing the ice to the height strictly necessary without the need of raising it up to the top, and of a certain number of passageways (starting from the elevator) that will permit of distributing the cakes over several points at once.

It is probable, too, that an arrangement will be applied in these ice houses that will permit of sawing the ice in regular blocks, instead of the very irregular ones that have hitherto been obtained. From a commercial standpoint, it would be very advantageous to introduce this improvement.

The ice is shipped in hermetically closed cars, strewed with straw, which enter a hermetically closed passage, wherein the loading is done. It is covered with a frame lined with a layer of straw four inches in thickness, and the whole is enveloped in woolen blankets. The ice is thus capable of traveling without melting to any considerable degree. A large quantity of it is forwarded to Paris.—*Le Genie Civil.*

THE USE OF BETON IN THE CONSTRUCTION OF PORTS.

WE herewith give a summary of the four methods of constructing jetties recommended by Mr. Kinipple in a memoir presented to the London Society of Civil Engineers.

1. *Walls Established in Place.*—A beginning is made by dredging the place where the mole is to be constructed, and then the earth is covered with a layer of beton, so as to obtain a regular base.

Next, the construction of the two walls is begun.

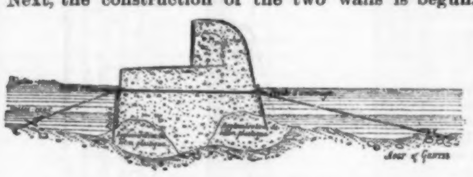


FIG. 1.—BREAKWATER WITH FRAME.

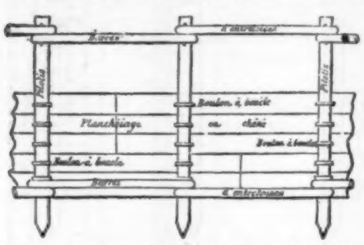
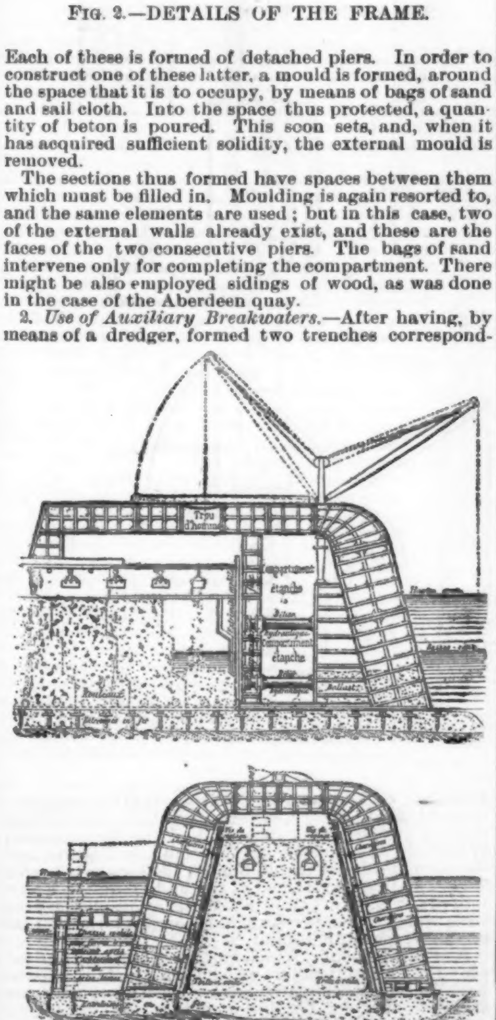


FIG. 2.—DETAILS OF THE FRAME.

Each of these is formed of detached piers. In order to construct one of these latter, a mould is formed, around the space that it is to occupy, by means of bags of sand and sail cloth. Into the space thus protected, a quantity of beton is poured. This soon sets, and, when it has acquired sufficient solidity, the external mould is removed.

The sections thus formed have spaces between them which must be filled in. Moulding is again resorted to, and the same elements are used; but in this case, two of the external walls already exist, and these are the faces of the two consecutive piers. The bags of sand intervene only for completing the compartment. There might be also employed sidings of wood, as was done in the case of the Aberdeen quay.

2. *Use of Auxiliary Breakwaters.*—After having, by means of a dredger, formed two trenches correspond-



FIGS. 3 AND 4.—MOVABLE SHIELD FOR THE CONSTRUCTION OF BREAKWATERS.

ing to the two lines of the base of the work, a stratum of beton is laid and piles are inserted in it. These, properly fastened, extend in the direction of the two surfaces of the jetty. In addition to being connected by ropes, as shown in Fig. 1, these piles are connected with each other, as shown in Fig. 2. There results, therefore, a continuous facing along the two future sides of the mole. After this, there are erected transverse walls, which, as in the preceding case, are constructed in a sort of mould formed of bags of sand. Then each cell is filled in turn with beton.

3. *Use of Metallic Caissons.*—After having dredged a channel and filled it in with beton, so as to obtain a regular level, a number of metallic caissons, that have been prepared in advance and placed on the shore, are sunk one after another at the place that they are to occupy, and are filled in with beton when the weather is favorable. To make these caissons stable, their lower part is formed either of masonry or a bed of wooden joists consolidated by Portland cement. The juxtaposing of the two consecutive caissons must be done with a certain amount of care, and the proposed method of making the joints is very analogous to that used in the construction of the Girvan jetty. As for the body of the work, that is obtained by filling in the empty spaces with beton. Of course, all that precedes applies to the lower portion of the mole only, for, as soon as the level of low tide is exceeded, the ordinary processes suffice perfectly.

4. *Use of a Protecting Shield.*—For the purpose of constructing a jetty, not in detached sections, designed to be connected later on, and not in horizontal sections, but in such a way as to be continuous, so to speak, Mr. Kinipple proposes the use of a protecting shield, after the example of what was done by his advice at Girvan. The ground, after being dredged, receives a stratum of beton traversed by strong pickets, upon which rests a sort of flooring. As for the shield (Figs. 3 and 4), that embraces the mole for quite a great length, protecting the newly erected portion from the action of the sea. At the extremity, and separated by a diaphragm, there are two compartments, one of them contiguous to the front of the structure and occupied by the workmen, and the other utilized for the maneuvers. To effect the shifting, the lateral walls, properly jointed by screws, are raised (Fig. 4), and a forward motion is given by means of the hydraulic apparatus shown in Fig. 4. When the shield rests upon the earth again, the diaphragm can be pushed forward and everything be placed in its former state, with the difference merely that the apparatus has been moved a certain distance along the sea wall. In the upper part of the work there are two passages in which move skips actuated by an endless cable. These serve for the carriage of the materials. At the extremity of the shield there is a crane, which, when desired, can be let down against the upper part of the shield.—*Le Genie Civil.*

RECENT PROGRESS IN THE USE OF CONCAVE GRATINGS FOR SPECTRUM ANALYSIS.

By Professor H. A. ROWLAND.

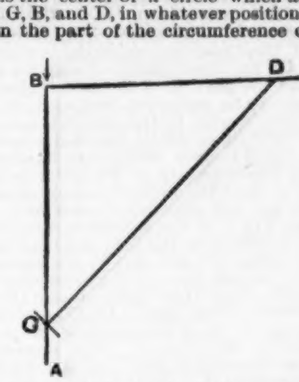
THE author referred to the paper he had read last year before the British Association on a similar subject. Since then, however, he had by means of a new and far better dividing engine succeeded in producing gratings far surpassing those exhibited then. In setting oneself to the task of producing a grating which should give the best attainable results, it is important to discover what kinds of defects in the gratings are most injurious. He had found that the linear errors—that is to say, errors in the spacing of the lines—had no effect except to cause the focus to vary slightly from one part to another. But a periodic error—caused by want of truth in the screw of the dividing engine—was all-important. With a grating in which there was a periodic error, the single line of lithium, for example, instead of appearing as a single sharp line, would be seen surrounded by "ghosts," that is, by numerous reproductions of itself on either side of it, and getting more and more dim as they got further away from the true lithium line. In the case of one grating, in making which the corrector had purposely been caused to exaggerate the periodic error instead of correcting it, the D line of sodium was seen surrounded by perhaps as many as fifty "ghosts." The correction in the new machine is, however, so nearly perfect that none of these "ghosts" are apparent to the naked eye, though some become slightly visible upon a photographic plate which had been rather over-exposed. A grating one decimeter long had been ruled which had nowhere an error of more than $\frac{1}{1500000}$ part of an inch beyond the first tenth. This first tenth part of the grating where the engine had begun its work was not quite so good, having an error of about $\frac{1}{500000}$ of an inch. There were in this grating 10,000 lines to the inch.

The concave gratings which the author had prepared and used were spherical, not parabolic, and had a 20 ft. focal length, with a 6 in. surface. It might seem to those who knew nothing practically of the process of ruling gratings, that when the dividing engine had been got to run well, all that had to be done was to put a diamond in the machine and proceed. It did not strike them that the procuring of a splinter of diamond with a suitable point for ruling 10,000 lines to the inch was not an easy matter. A mechanic had been at work now for more than two months endeavoring to obtain a splinter to rule a grating having 20,000 lines to the inch, and so far as the author knew, that splinter had not been found yet. The dividing engine was driven by water power at constant pressure, and kept in a room where the temperature did not vary much. A large grating would take four or five days to rule, and the engine had to be allowed to run for some hours before the work was put on, in order that it might be running truly when the ruling began—in fact, it would be better to let it run for a day or two.

With his new gratings the author had set to work to obtain a photographic chart of the lines in the solar spectrum of a far more accurate nature than it had been possible until then to produce. For this purpose it was necessary to have a correct knowledge of absolute wave lengths. Angstrom was known to be inaccurate, so that the following experimental results were taken, valued, according to the author's judgment, in the manner given in the third column, and a mean result arrived at in this way:

Angstrom	5895·81	1
Muller and Kempf	5896·25	2
Kurlbaum	5895·90	2
Peirce	5896·20	5
Bell	5896·20	10
Mean	5896·156	

A concave grating has the advantage that the spectrum is always in focus; also photographs produced by its means are normal—that is, the distances upon them are proportional to the wave length. Moreover, all photographs taken from the same spectrum are upon the same scale, no matter what portion of the spectrum is chosen. The author arranged his apparatus in a darkened room, as shown by the annexed diagram. Along the line, A B, a girder would be placed, and a second girder along B C. Upon these girders run little trucks, which carry between them a third beam, G D, bearing at one end the concave grating, G, and at the other the photographic plate, D. The middle point of G D is the center of a circle which always passes through G, B, and D, in whatever position G D may be, and upon the part of the circumference of that circle



remote from G the spectral image is produced; but the image is normal only at the further end of the radius, which has the grating at the near end. The beam of sunlight enters along the line, B G, and is reflected along G D, the latter being in the author's apparatus a distance of 21 ft.

There are many advantages in this arrangement. Among others, the fact that the light passes through no glass, that all the spectra which fall upon the photographic plate simultaneously print themselves there, so that photographs of overlapping spectra may be thus taken, and that the image is astigmatic, are some of the chief which tend toward the production of the almost perfect photospectra which the author exhibited. In order to map a spectrum, its photograph is taken on a long glass strip, and a second strip of the same dimensions, but carrying the scale upon it, is placed above the first, and the two are then placed in the enlarging apparatus, and a joint photograph of the two is obtained. The author's object in this work was chiefly the preparation of standard photographic spectra for reference; he also desired to investigate the theory of the distance between the lines. As far as the former object is concerned, the photographic charts produced had a degree of perfection never before approached. A photograph of the carbon lines showed that nearly all were double.

In reply to Prof. Stoney, the author explained that the photographic plate was slightly bent, in order to coincide with a part of the circle alluded to.

M. Janssen remarked upon the great use that these perfect photographs would have in keeping a permanent record of the state of the sun at the present time, in order that future observers might detect any change.

THE LIPPMANN MAGNETOMETER.

M. LIPPMANN's discovery of the action of a magnetic field on a column of mercury through which a current is passing has been recently utilized by M. George Miot, of Paris, in the construction of an "inductometer," or instrument for determining the strength of the magnetic field (perhaps "magnetometer" is the better word for this class of instrument). The effect of the magnetic field, it will be remembered, is to cause the mercury to rise to a height depending upon the strength of the current, or of the magnetic field when the current is constant. The inductometer is shown in the accompanying engraving, Fig. 1; and Figs. 2 and 3 show respectively sections on the lines 1 2 and 3 4.

The apparatus consists essentially of a tube, A B C,

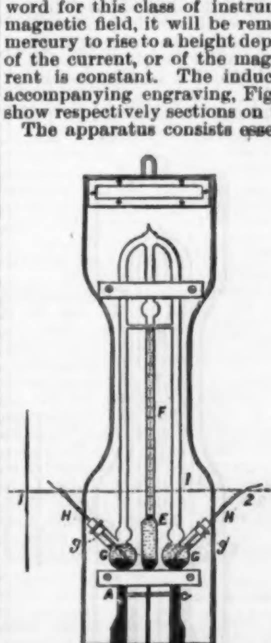


FIG. 1.

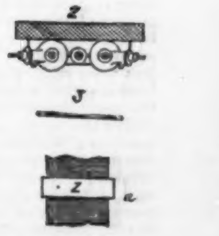


FIG. 4.

the lower portion of which is flattened in such a way that it can be placed in a short magnetic field, such as found in dynamo-electric machines. To the base, B, is soldered a capillary tube, D, which is surmounted by a

bulb, E, above which rises a graduated tube, F. The two other bulbs, G G', are placed upon the extremities of the U-shaped tube, and are provided with branch tubes, gg', into which the mercury is poured until its level reaches to about the middle of the three bulbs. Then on top of the mercury are poured several drops of glycerine into the bulbs, GG', and a few drops of water or alcohol into the tube, F.

In order to preserve the mercury and other liquid from contact with the air, the U-shaped tube is prolonged above the two bulbs to unite again with the central tube at the top of the apparatus, as shown in Fig. 1. In this way the liquids are inclosed in an atmosphere of their own, having no communication with the external air.

In order to measure the intensity of the magnetic field by this apparatus, metal rods, H H', are introduced through the tubular branches, $g\,g'$, into the bulbs, G G', so that their ends are immersed in the mercury. The rods, H H', are then connected with the poles of a generator, and the part, B, of the tube is placed in the magnetic field to be examined, and with the tubes, B and D, at right angles to the line of magnetic force. The mercury will immediately rise in the bulb, E, and force up the liquid therein, which may be colored, into the tube, F. The diameter of the latter being much smaller than that of the bulb, the movements of the liquid therein are correspondingly amplified.

Referring to Fig. 4, if it is desired to measure at the point, a, the intensity of the field of a magnet pole, Z, it suffices to place at a the part of the apparatus representing the intersection of the horizontal tube, B, with the middle tube, D, to pass through the tube, B, a known current of, say, from 1 to 10 amperes, and to read the change of level produced in the column of colored liquid in the tube, F. If d represents this height read on the scale, F, and C be the current traversing the apparatus at a, then the magnetic force, H, at that point will be represented by $\frac{d}{KC}$, K being the constant of the instrument.

The rise of the mercury is due to the reaction between the electric current traversing the tube, B, and the magnetic field. For the examination of a vertical field it suffices to curve the lower part of the tube at right angles.—*The Electrician.*

A NEW AIR PYROMETER.*

By Professor J. WIBORGH, School of Mines, Stockholm.

GAY-LUSSAC, Dulon, Rudberg, and Regnault, having by their famous experiments decided the coefficient of the dilatation of the air, instruments similar to those which they had employed for this purpose were used as measurers of temperature, and were called air thermometers, or, if they were specially designed for ascertaining greater degrees of heat, air pyrometers.

In consequence, however, of the construction of these instruments, and the care and practice necessary for their proper use, they have only been employed as measurers of temperature in the cause of science, or, at most, for grading other pyrometers designed for the needs of industrial pursuits.

Though the coefficient of the expansion of the air, even at a very high degree of heat, is constant,† still the expansion of the air ought to be the surest base for the construction of a reliable pyrometer, and, therefore, it seemed to me of great importance that these air pyrometers should be brought to a simpler and a more practical form.

Before proceeding to a more particular description of my contribution to the solution of this important question, I will first say a few words concerning the two principles which have hitherto been followed when constructing pyrometers. These are, first, that a certain given amount of air, even when heated, is kept at the same volume, when the requisite pressure gives a measurement of the increase of temperature; and the second, that the air is kept under unvaried pressure, when the degree of heat is determined by the change of volume.

These two systems are seen in Fig. 1 annexed, where V represents a thermometer bulb filled with air, which, by means of the capillary tube, A, is connected with an open manometer, the one part of which, V', is graded in cubic centimeters, and the other, B, consists of a longer vertical tube. The manometer tubes, V' and B, are connected in their lower part, and, furthermore, communicate with a caoutchouc ball, K, containing mercury, which is driven up into the manometer when the vessel is compressed. By another capillary tube, C, provided with a tap, D, the thermometer bulb, V, can be put in communication with the outer air.

The volume of the capillary tube is supposed to be so slight that it need not enter into the calculation.

Should this instrument, according to the principle first mentioned, be used as a thermometer, the tap, D, is opened, and the mercury is driven up to the mark, m, close to the capillary tube. The surface of the mercury will then be equally high in both the manometer tubes, since the same pressure—that of the atmosphere—acts on both of them. Afterward, when the tap, D, has been shut, the bulb, V, is exposed to the temperature sought, when the inclosed air dilates and forces up the mercury, so that in the manometer tube, B, it rises above the mark, m. On forcing into the manometer so much quicksilver that its surface rises in the tube, V', to the mark, m, so as to reduce the volume of the air to its original volume, the quicksilver in the tube, B, rises still further, say to h; this height, h, then gives a measurement of the temperature, according to the following simple formula:

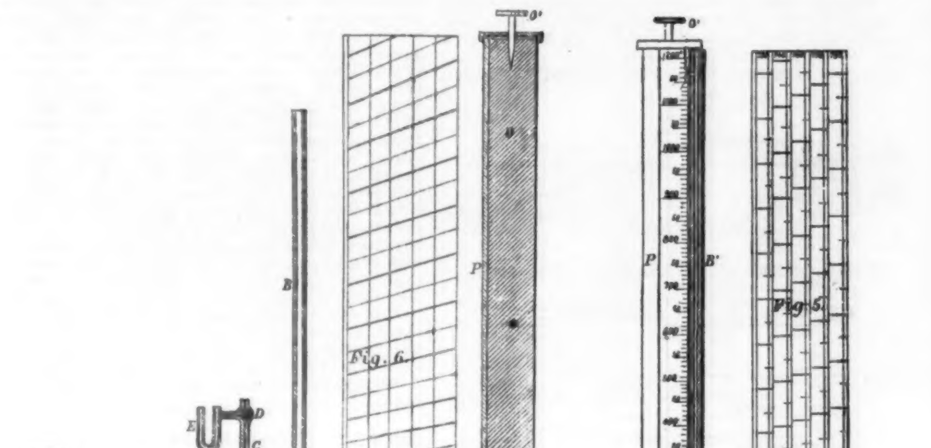
$$h=H\,.\,a\,.\,t.$$

In this, h signifies the higher pressure which is requisite for the air being kept at an unvaried volume; H the prevailing barometrical pressure for the time being; a the coefficient of the dilatation of the air; and t the increase of temperature of the air in the bulb, V. By giving this form to the air pyrometer, as seen by the formula, we are independent of the size of the thermometer bulb, and the excess pressure, h, is proportional to the increase of temperature. But this excess pressure, on the other hand, is so important that, for an increase of temperature of the air in the thermometer bulb of 270 deg., h increases a whole atmosphere, or 760 mm.; and this circumstance, as can easily be understood, renders it impossible to use this thermometer for ascertaining high degrees of temperature, so that it never can be a pyrometer in the real sense of the word.

If the same instrument is to be used as a thermometer, according to the second principle, the mercury is adjusted as before to the mark, m, but while the thermometer bulb is warmed $t°$, by which the air is dilated, part of the air is allowed to escape freely into the graduated tube, V', and causes the mercury in the manometer to sink, so that it is constantly at the same level in both the tubes, and the inclosed air is thus kept at the same pressure. For a given increase of temperature, t, the air dilates with a certain volume, V', which may be read on the graduated tube, and thus becomes a measurement of the temperature according to the formula

$$V'=V\frac{a\,t}{1+a\,t}$$

supposing that the volume of air, V', at the reading has the same temperature that it originally had, and that the barometric pressure has not changed during the experiment.



A NEW AIR PYRCMETER.

In this case we are independent of the barometric pressure, but the increase of volume is not proportional to the increase of temperature, and the influence that this latter circumstance may exercise on the possibility of making nice calculations of temperature may be seen from what follows. Suppose the thermometer bulb that is heated contains 10 cubic centimeters. When the temperature rises from 100 deg. to 200 deg., it corresponds to a difference of volume of 1·55 cubic centimeter; but between 900 deg. and 1,000 deg. the difference of volume is only 0·19 cubic centimeter. From this it is plain that the sensibility of this thermometer decreases as the temperature increases.

If the bulb of the thermometer be made larger, an increased volume, V', can certainly be read, as shown by the formula, but in these cases practical inconvenience is occasioned by being obliged to use a large thermometer bulb, and the readings must therefore be made with this pyrometer with the greatest nicety. In order to make this possible, Professor O. Pettersson, of the high school of Stockholm, has made a very ingenious improvement, the principle of which is shown in Fig. 1. He has combined the capillary tube, C, with a small manometer, E, which contains a light fluid, and is therefore very sensitive. When the surfaces of the mercury in the manometer tubes are almost on the same level, communication is opened to this manometer by means of the tap, D, by the help of which the mercury can afterward be regulated to a nicety, so that the inclosed gas obtains atmospheric pressure. This, however, is not enough; the temperature of the volume of air, V', ought also to be ascertained with the same accuracy if any useful results are to be obtained, and this part of the manometer must therefore be surrounded by water of a known temperature, which makes the handling of the instrument extremely inconvenient. From the above it will be seen that air pyrometers founded on the principles hitherto used cannot possibly be of practical use for measuring temperature in the service of industry.

On looking at Fig. 1 a little more closely, it will easily be seen that there is another mode of constructing air pyrometers. The mercury can be adjusted to the mark, m', and the tap, D, be left open, so that the volume of air, V, is in communication with the outer air. As the thermometer bulb is heated or cooled, a certain quantity of air flows out or in, as a matter of course, so that the air remaining in the thermometer bulb is always under atmospheric pressure.

When the temperature is to be ascertained, the tap, D, is shut, and the mercury is driven into the manometer as high as the mark, m, when a certain given volume of air, V', is forced into the bulb of the thermometer. If the air, when forced into the bulb, is $t°$ warm, and the temperature of the bulb is T°, the former is heated T°—$t°$, and being retained in the bulb, requires a certain pressure, h, over and above the atmospheric pressure, which excess pressure, h, becomes a measurement of the temperature sought, T.

It is this principle, which has never before been employed for air pyrometers, which forms the fundamental basis of my new air pyrometer, the theory and construction of which I will now explain.

The Theory of the Pyrometer.—Into the thermometer bulb, V, which contains air of atmospheric pressure of the warmth of T°, a certain volume of air, V', at the temperature of $t°$ and atmospheric pressure, is to be forced and heated to T°.

If the pressure was unvaried, the entire volume of air after heating would be

$$V+V'\left\{1+a(T-t)\right\}$$

but as the volume of air, V', must be contained in the thermometer bulb, V, the pressure must also be altered

* Paper read before the Iron and Steel Institute at Edinburgh.—*Engineering.*

† V. Meyer and Langer have proved that the dilatation coefficient of oxygen and nitrogen is constant up to 1,700 deg. Cent. (*Wagner's Jahresbericht*, 1885, page 380).

with a certain magnitude, h, from which the following equation is obtained:

$$\frac{\left[V + V'.\left\{1 + a(T-t)\right\}\right].H}{H+h} = V \quad . \quad . \quad (1)$$

or

$$h = \frac{V'}{V}.H + \frac{V'}{V}.H.a(T-t) \quad . \quad . \quad (2)$$

or

$$T-t = \frac{V.h - V'.H}{a.V'.H} \quad . \quad . \quad (3)$$

In these formulæ the volume of the capillary tube is not taken into account, since, in relation to the volumes, V and V', it must be small enough not to influence the determinations of temperature to any considerable degree. For the same reason no account is taken of the dilatation of the bulb of the thermometer; but should there be a wish to allow the latter to enter into the calculation, then, instead of formula (2), we have

$$h = \frac{V'.H}{V.(1+KT)}\left\{1 + a(T-t)\right\} \quad . \quad (4)$$

where K is the coefficient of cubical expansion of the material of which the bulb of the thermometer is made. From the formula (3) it is seen that the thermometer only gives the difference of temperature between the volumes, V and V', and from (2) that for $T=t$, *i. e.*, when both the volumes of air are at the same temperature, h is equal to the first term of the equation $\frac{V'}{V}H$, which thus represents the position of the point of zero of the instrument.

The second term in the formula (2), on the contrary, shows the excess in the height of pressure above the point of zero, which is furthermore necessary for pressing the one volume of air, V', into the other, V, as they are at different temperatures. These excesses, as is seen from the formula (2), are proportional to the differences of temperature; from which it again follows that the thermometer for a certain increase of heat must give as great a result, whether the temperature be high or low. From what has just been stated it follows, moreover, that the temperature sought, T (the temperature of the thermometer bulb), can only be obtained after adding the degree of heat of the volume of air, V', before it is forced in, to the temperature, or, more properly speaking, the difference of temperature, which is shown by the instrument.

From the formula (2) it also follows that the position of the point of zero and the excess pressure occasioned by the differences of temperature are both dependent on the barometric pressure, which must therefore be known, as also the ratio of $\frac{V'}{V}$. The larger the bulb of the pyrometer is made in relation to the volume of air, V', which is to be pressed in, the smaller must the excess of temperature be which shows a certain effect on the manometer, and these air barometers can therefore be made to meet different requirements, so that they give greater or less results for a certain degree of heat, in full accordance with the case of the common mercury thermometer, where the same thing is arrived at by varying the volume of the bulb of the thermometer and the diameter of the tube of the thermometer.

It is plain that this air pyrometer can be used just as well for measuring cold as heat, for if the bulb of the thermometer is colder than the volume of air, V', the second term in the formula (2) becomes negative, which means that the pressure h sinks below the point of zero, but at a distance from it which answers to the difference of temperature in question.

The Construction of the Pyrometer.—Figs. 2, 3, and 4 show the construction of the pyrometer in question, where it is chiefly designed for determining the temperature of the blast of a furnace. The bulb of the thermometer, V, which holds about 12 cubic centimeters, forms the one end of the porcelain tube, A, the outer diameter of which is 20 mm., while the inner is but ½ mm., so that it can be regarded as a capillary tube. This tube, which is to sustain the other parts of the instrument, must be of great strength, and for this reason the thickness of the material is so great. The tube is cemented into a metal casing, H, which is screwed firmly to a metal cylinder, H', through which the capillary tube is connected with the manometer, B V' B'. The glass tube forming the manometer is at first capillary, but at m it is for a length of about 10 mm. made somewhat wider, 1½ mm. to 2 mm., after which a further enlargement commences for holding the volume of air, V'. When determining the temperature, this volume, V', is to be led into the bulb of the thermometer, V, which should be made about ten times greater than V'. At m', where the longer manometer tube, B', is extended, the inner diameter is about 3 mm., the outer about 8 mm., and below the glass tube is bent and connected with a caoutchouc ball, K, which contains mercury. The ball K is placed in a metal box M, with a movable lid, N, which, by means of a screw, S, can be pressed down into the box. Thus the ball is squeezed, and the mercury driven into the manometer tubes.

The screw, S, is turned by a metal plate, S', which is loosely fixed on the tap-like end of the screw, so that this plate may be easily taken away, and meddling and careless driving up of the mercury through the manometer tube, B, into the bulb of the thermometer, thus injuring the instrument, is prevented.

To protect the tubes of the manometer, they are inclosed in a small rectangular box, D, made of metal, the front being formed of a glass plate, G. The longer tube of the manometer, B', proceeds through this box, and runs along the folded edge of a metal tube, P, which surrounds a wooden cylinder, O. On this cylinder, which can be turned by the knob, O', the scales are fixed, a segment of the metal tube being cut away nearest to the manometer, so that the scale may be visible. By turning the scale cylinder, the proper scale, or that answering to the barometrical pressure, may be brought to the tube of the manometer.

In order to prevent dust from penetrating into the open tube of the manometer, B, and destroying the mercury, a little cotton wool is placed in the upper end of the tube, on which a glass cap may afterward be hung.

If the volume of air, V', be as warm as the bulb of the thermometer, and the mercury is forced up to the mark, m, as has before been stated, it rises in the manometer tube, B', to a certain height, which forms the point of zero of the thermometer corresponding to the prevailing barometric pressure.

In order to ascertain which is the correct scale, it is thus only necessary to turn the scale cylinder, so that the scale whose point of zero coincides with the height of the mercury reaches the manometer tube; but on the other hand, when the instrument is so placed that V is warmer than V', it is, of course, impossible to decide the correct scale in this manner. To avoid the consequent use of a separate barometer, a third tube, Q, ending in a ball, Q', is applied to the tube of the manometer, which, below the manometer tube, B', opens into the common tube, R. When the mercury is forced into the manometer, it of course rises in the tube just mentioned, and for the point of zero of the instrument attains a certain height, where a mark (r) is notched. Thus the same principle is applied as for the pyrometer, viz., that a certain given volume of air is forced into another. But as the tube, Q, and the ball, Q', are of the same temperature, the pyrometer's point of zero may be determined by the aid of this mark (r), even should V be warmer than V'.

As the pyrometer shown in Figs. 2 to 4 is chiefly intended for determining the temperature of the blast of a furnace, the instrument should be of solid construction and easily applicable. For the protection of the lower part of the china tube, A, which contains the thermometer bulb, and is therefore more fragile, it is at that part surrounded by a perforated metal covering, x, but the upper part of the same tube is not covered with metal, partly because, in consequence of its construction, it is sufficiently durable, and partly because, on account of the small power which porcelain possesses of conducting heat, it is intended to serve to isolate the other parts of the instrument from the hot gas main. At the upper part the metal covering is provided with a somewhat conical ring, y, which rests on a suitable opening in the gas main when the pyrometer is put in it. As a protection against the radiating heat of the gas main, a plate of metal, Z, is applied to the metal ring just mentioned.

It often depends on local conditions whether the pyrometer can be conveniently placed above the gas main or on one side of it, and the instrument should therefore be constructed so that it may be used in either case. For this purpose the metal cylinder, H', which connects the capillary tube of the porcelain tube with the manometer, is arranged so that the pyrometer tube, A, can be moved and replaced by the screw plug, U, which in this case must be fixed in the place formerly occupied by the tube of the pyrometer, so as to shut off all communication with the outer air at this point.

For cementing both the tube of the pyrometer and also that of the manometer in their respective metal sockets, a cement is used made of finely ground protoxide of lead (litharge), which is well mixed with so much glycerine that the mass becomes pretty thick. This cement hardens quickly (within a few hours), tightens extremely well, and can be heated to about 250 deg. C. before it splits.

In order to avoid stopping the capillary tubes when cementing, the two tubes are connected by a metal wire carried through them, when the end of the tube is held slightly outside the metal socket, and is covered with a layer of cement. The tube is afterward pushed gently into the metal socket, and the interstice is again well filled with cement. After an interval of about half an hour the superfluous cement outside the socket is removed, and the metal wire is drawn out.

When transporting the pyrometer the mercury must be shut off, so that it cannot escape into the tubes of the manometer. For this purpose, between the caoutchouc ball and the manometer tube there is a clamp, E, which consists of a couple of metal plates connected by a screw, S''. This squeezes the neck of the caoutchouc ball when, by tilting the instrument, the mercury has run into the ball. The screw, S'', is turned by the same metal plate, S', which is used for the screw, S. The temperature of the volume of air, V', before being forced in, is the same as the temperature of the surrounding air, which is determined by a thermometer, T, placed close to the manometer tube.

Calculation and Drawing of the Scale of the Pyrometer.—Before the scale can be calculated and drawn, the position of the point of zero must first be determined. For this purpose a fine but plainly visible scratch, m, is made on the tube of the manometer, just below that place where the capillary tube ends. This being done, the bolt, U, is unscrewed, and the mercury in both the tubes of the manometer is then under atmospheric pressure. The mercury having been raised to the mark, m, the height to which it then rises in the other tube is ascertained by means of a cathetometer, or is marked for the occasion on this tube. The mercury is then again sunk so that it only mounts to m'—*i. e.*, below the tubes, Q and B'. The screw bolt is then again adjusted, and in order that it may completely close the capillary tube, a thin piece of caoutchouc, of at most a half millimeter in thickness, and of somewhat smaller diameter than the screw, U, is placed before the opening.

A similar packing must also be employed when screwing the pyrometer tube into the socket, H, although with this difference, that a small hole is then made in the middle of the thin piece of caoutchouc, so that the capillary tubes are in communication, the one with the other.

If the mercury be now again forced to the mark, m, in the other manometer tube, it rises to a certain height, which is also measured or marked with a mark on the tube. Should these two observations have been taken during a known atmospheric pressure, H, and while the volume of air, V, as also V', are of the same temperature, the difference in the height of pressure, h, which is a function of these two measurements, is just the point of zero of the thermometer at the atmospheric pressure in question, according to the formula already mentioned,

$$h = \frac{V'}{V}.H,$$

and since both h and H can easily be determined, the ratio $\frac{V'}{V}$ is thus arrived at for this instrument; and from this formula, moreover, the position of the point of zero of any atmospheric pressure can easily be determined.

From the second term of the formula (2)

$$\frac{V'}{V}H.a.(T-t)$$

it can also be calculated how far, or to what height above the point of zero, the height of pressure must be increased for an atmospheric pressure, H, and a certain difference of temperature between the two volumes of air, V and V', of, for instance, 1,000 deg. Celsius. The position of the point of zero, as also the length of the scale for a certain atmospheric pressure and a difference of temperature of, let us say, 1,000 deg., having thus been determined, it is easy to draw this scale as may seem most suitable for the readings; for since the excesses in the height of pressure are proportional to the differences of temperature, it is only necessary to divide the length of the scale found by, for instance, 100, in order to ascertain how large that part of the scale is which answers to an increase of temperature of 10 deg.

In this manner the scales of temperature can be calculated for a few certain atmospheric pressures, as, *e. g.*, 730, 745, 760, 775, and 790 mm., and be drawn and fastened to the wooden cylinder, O. When drawing the scale, two parallel lines l and l', Figs. 5 and 6, are drawn at a distance from each other, like that of the periphery of the wooden cylinder. The area between these lines is then divided into five fields of the same width, and in these scales are drawn answering to the atmospheric pressures just mentioned. The point of zero for a scale of 730 mm. of atmospheric pressure is chosen arbitrarily, and the situation of the other points of zero is calculated in proportion to this.

The scales having been drawn, the complete scale is cut out, rolled together, and pasted in such a manner that the lines l and l' coincide, after which it is threaded on to the cylinder, and fastened with a few small pins, care being taken that the point of zero for a certain atmospheric pressure is at a proper height. The scale should then be varnished, so that dust and soot cannot so easily adhere to it.

Instead of drawing the scales in the manner just described for several different atmospheric pressures, as shown on Fig. 5, it is also possible to limit the operation, simply calculating the scales for the highest and lowest probable atmospheric pressures, viz., for 730 mm. and 790 mm., and after grading them on the lines l and l', connect the respective parts of the scale, when sloping lines are obtained, which represent the temperature of every intervening atmospheric pressure.

Management of the Instrument.—When unscrewing or removing the manometer tube, A, care must be taken that the instrument be not leaky. In order to ascertain this, the mercury is screwed up to the mark, m, when it should remain at an unvaried height in the other manometer tube for a period of at least two minutes. Should there be any leakage, the mercury sinks in the tube last mentioned, but rises in the other, and mounts into the capillary tube.

It must be remembered when making such an observation, as also when determining temperatures in general, that in consequence of compression a slight increase of temperature occurs when forcing in the volume, V'. If V and V' are equally warm, the above mentioned increase of temperature of the air causes the height of the mercury, h, to fall slightly immediately after the air has been forced in, and only after the lapse of half a minute or thereabout does it again become constant; but should V' be colder than V, forcing in the colder air causes a decrease of temperature, and in this case the compression acts favorably, since it contributes toward making the air in the bulb of the thermometer assume more quickly the required temperature, T, or that which the bulb of the thermometer was at before the volume, V', was forced in.

When a determination of temperature is made, it often happens that if the mercury has been driven up to the mark, m, on afterward loosening the screw, S, the mercury sinks rapidly, not only in the manometer tube, B', but in both the tubes at the same time. This circumstance does not depend either on there being a leakage in the instrument or on the compression, but on the elasticity of the caoutchouc ball.

The following rules ought to be observed when handling the instrument:

1. The mercury should never be forced higher than the mark, m.

2. After every observation the mercury should at once be brought down, so that its surface is below the inlet to the tubes, B' and Q.

3. Observations should not be attempted when the bulb of the thermometer is in a state of rapid increase of temperature or of cooling.

4. Should the prevailing atmospheric pressure not be known, the quicksilver must first be driven up to the mark, r, of the tube, Q, the scale cylinder being then turned until its point of zero is at the same height as the mercury in the tube of the manometer. This is the correct scale from which the readings of temperature should be taken, after having again forced up the quicksilver to the mark, m.

5. When making very accurate determinations of temperature, 15 to 30 seconds should be allowed to elapse before taking the readings, during which time the height of the quicksilver is constantly regulated so that the surface is at the mark, m.

Against the construction of the pyrometer the objection can be made that the air, the dilatation of which is here employed for determining the temperature, has not previously been freed from moisture. In a case like this, however, the usual amount of moisture of the air cannot cause any remarkable effect, more especially as the aqueous gas present in the air is more like the permanent gases in respect to the effects of compression and expansion when the temperature rises.

For determinations of temperature only designed for practical purposes, it can therefore be of little importance whether perfectly dry air be used or no; but if, as in the case of strictly scientific examinations, this source of error is to be avoided, it is easily done by lengthening the manometer tube, B', with a tube which contains either pieces of chloride of calcium or pieces of pumice stone moistened with sulphuric acid, when, of course, only dry air can enter the tubes of the manometer and the bulb of the thermometer.

Compared with measures of temperature of the same sort that have previously been used, this new air pyro-

meter has several important advantages, as it is of a simpler construction, and can be handled by a common workman; it gives as great a result for a certain difference of temperature, whether the temperature itself be high or low; the determinations of temperature can be made very rapidly, but yet with great nicety; the bulb of the thermometer is not exposed to any difference of pressure outwardly or inwardly, other than during those moments when the observations of temperature are made; lastly, the pyrometer, without further seeing to, is ready at any moment for readings of temperature; all these being qualities which should contribute toward fulfilling that purpose for which it has been constructed, viz., of being a practical and reliable pyrometer in the service of industry.

INTRODUCTORY ADDRESS ON THE ELECTROMOTIVE PROPERTIES OF THE HUMAN HEART.*

Delivered at St. Mary's Hospital Medical School, at the Opening of the Session, 1888-89.

By AUGUSTUS D. WALLER, M.D., Lecturer on Physiology.

THERE is a growing disposition to regard introductory lectures as a survival—a survival unfit for the times. But, like all other customs, this custom, having had its particular reason of being in the past, lives on with altered ends and in changing shape. In its primitive shape, as a general guidance addressed to those who have just enlisted, it may be no longer necessary nor acceptable, but it certainly cannot be unfitting in any time that each member of a teaching body should in turn be called upon to say, in the presence of his fellow-workers, that which he thinks to be the best worth saying. My particular task on this occasion has been made easy by my colleagues; it was suggested to me that I should speak about physiology, and I am very willing to do so. Let me at once explain why.

The St. Mary's Hospital Medical School is at present rapidly growing, not merely in size, but in complexity; and it has within the last few years developed two entirely new organs, a physiological and a pathological laboratory. It is not unnatural that those who are most responsible for the development should be glad to hear something about the functions of these organs, and should expect from me, as the person responsible for the physiological laboratory, some report of progress during the last four years. I am, on my side, very willing that my duty as your introductory lecturer should take this form, which will allow me, not, indeed, to report progress in its full and formal sense, but to report on an item of progress; and I shall, therefore, occupy the greater part of the thirty or forty minutes allowed me in describing a new bit of knowledge, and how it has been obtained. Our new bit of knowledge is about the human heart, not in a metaphysical or figurative sense, not its motives, but only its action; not its power, but its electrical potential. Put into a single sentence, I am going to describe how the heart of man can be shown to act as an electrical organ, and what we learn from such action.

It is a well known fact that every beat of the heart is accompanied by an electrical disturbance. The nature of this disturbance has, moreover, been studied and understood with the assistance of cold-blooded animals, and in this laboratory, in particular, an investigation was carried out to learn whether or no warm-blooded animals manifest similar electrical disturbances. These I will not now enter upon, and will only make the passing remark that, while to all appearance the electrical disturbances are similar in the two classes of animals, they are not identically so. These seem to indicate that the contraction which at each beat of the cold-blooded heart runs down from the base to the apex, runs in the opposite direction in the warm-blooded heart. But this is only by the way, and I make no attempt to explain. It is to the next step that I invite your attention to-day, namely, to the human heart.

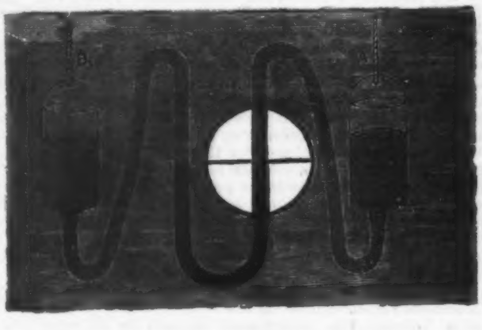
Led on from thought to thought, it occurred to me that it should be possible to get evidence of electrical action on man by connecting not the heart itself, which is obviously impossible, but parts of the surface of the body near the heart with a suitable instrument. Having verified this supposition, the next step was to see whether or no the same evidence can be obtained by connecting the instrument with parts of the body at a distance from the heart with the hands or feet. The answer was, as you can well see, satisfactory. Finally, I tried whether two people holding hands and connected with the instrument gave evidence of electrical shocks through each other, and I found they did.

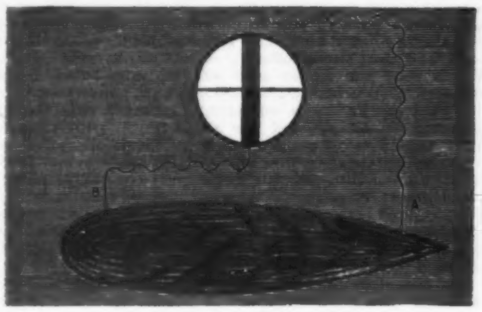
The only portion which I wish to explain in any detail is the second step in these experiments, namely, the analysis of the results which are obtained when a single individual, whether man, horse, or dog, is connected with the electrical indicator.

Let me briefly explain the principle of action of an electrical indicator by referring to this diagram, in which the effects of water pressure are compared with those of what I may call electrical pressure (potential is the correct term, but I take it to be part of my task to-day to avoid technical terms).

A and B are two bottles of water, each connected by flexible pipes with a bent tube half full of mercury. If the two bottles are at the same level, the mercury in the bent tube remains at zero, and it is evident that this is still the case if both bottles be raised together or lowered together. But if the bottles be moved unequally, either up or down, the level of the mercury will alter. It is obvious that if A is lower than B, the mercury in this limb of the tube will move upward, whereas if B is lower than A it will move downward. And if we imagine everything hidden from us by a screen with the exception of this portion of the tube which we can view through a circular opening, while the two bottles are being moved by unseen hands, it is obvious that we shall be able to tell by the movements of the index whether A is below B or B below A. If the mercury goes up, A is below B; if it goes down, B is below A.

Now this is what happens when the two ends of an electrical indicator are in connection with any two points, A and B, of a living body. If A and B are at the same level the index stands at zero, and it does not move if the two points are raised or lowered together to an equal amount. If the index moves up, we know that A is lower than B; if down, that B is lower than A.

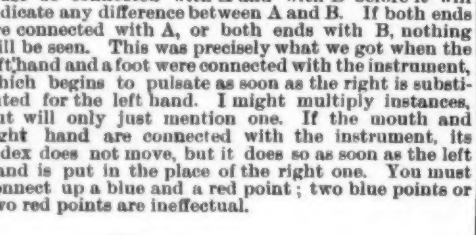




Let us now apply our instrument to the heart. This, which seems rather a bold proposition, is really a very simple and easy matter. We need simply dip the two hands into two basins of water which are in connection with our indicator, when we shall see that the mercury beats up and down with the pulse. These movements of the mercury are due to the electrical changes which occur with every beat of the heart. Or we may dip a hand and a foot each into a basin of water with a similar result, only it must be the right hand. The left will not do. This difference, apparently so curious and puzzling at first sight, which seemed unsymmetrical and irrational, is in reality most reasonable, and proved to be the master key which threw open the meaning of every subsequent experiment. The difference depends upon the unsymmetrical position of the human heart, which is tilted to the left side, somewhat as shown in this diagram.

Allow me to return for one moment to the physical A B C of the subject. The points, A and B, are respectively applied to the apex and base of the heart; and if with the contraction of the organ these two portions undergo any electrical change, the change will spread over the whole body, in accordance with known laws. I will say no more than that. The form of the change is represented by these oval lines. If the electrical level falls at A, it falls over the red area (see note and fifth diagram), which, as you see, includes the left hand and foot and the right foot. If the electrical level falls at B, it falls over this blue area, which includes the right arm and the head.

Now, it is obvious that the two ends of the indicator must be connected with A and with B before it will indicate any difference between A and B. If both ends are connected with A, or both ends with B, nothing will be seen. This was precisely what we got when the left hand and a foot were connected with the instrument, which begins to pulsate as soon as the right is substituted for the left hand. I might multiply instances, but will only just mention one. If the mouth and right hand are connected with the instrument, its index does not move, but it does so as soon as the left hand is put in the place of the right one. You must connect up a blue and a red point; two blue points or two red points are ineffectual.



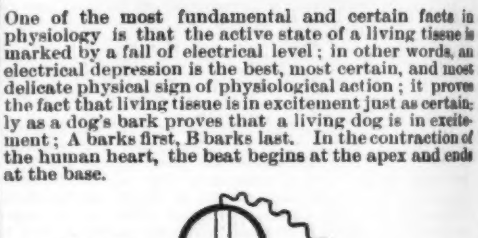
But this evidence does not stand alone. Cases every now and then present themselves with a transposition of the viscera, which are in such people situated just like those of a normal person as they would be viewed in a mirror. The heart, among other organs, is reversed, and, instead of pointing to the left, points to the right. As regards the electrical relations which I was following out, they were precisely as expected. The left arm was in this case the exceptional limb, and formed an effectual couple with any one of the other three limbs, but was ineffective in combination with the mouth. To make a long story short, the results were throughout as indicated in the diagram; any two blue points or any two red points in connection with the indicator were silent, but as soon as connection was made with a red point and a blue point, then the index moved with each pulsation of the heart.

Let us hear one more witness. The heart of a quadruped (dog, or cat, or rabbit, or horse) is placed far more symmetrically than in man; it is very nearly in the middle line, so that the changes of electrical level, whose foci are at A and B, spread straight up and down the body, not obliquely, as in man. The upper half of the body is under the influence emanating from B; the lower half under that emanating from A. Unlike what occurs in man, the two front paws coupled with an indicator are silent, while either front paw taken with either hind foot gives us the now familiar answer.

These are the principal facts. What can we learn from them with regard to the normal action of the heart? I must be content with simply stating the answers.

The fact that each beat of the heart gives an electrical change beginning at one end of the organ and ending at the other proves that the contraction does not occur throughout the mass of the heart at one and the same instant of time. If the two points, A and B, rose and fell together, there would be no alteration of the index. The movements of the index show that there is a fall of A at the beginning of the contraction and a fall of B at the end of the contraction.

One of the most fundamental and certain facts in physiology is that the active state of a living tissue is marked by a fall of electrical level; in other words, an electrical depression is the best, most certain, and most delicate physical sign of physiological action; it proves the fact that living tissue is in excitement just as certainly as a dog's bark proves that a living dog is in excitement; A barks first, B barks last. In the contraction of the human heart, the beat begins at the apex and ends at the base.



We have here the answer, and more than the answer, to a question which has often been asked but never settled—namely, does the heart (that is, the ventricles) beat simultaneously in every portion, or does the contraction take place progressively, as a state of action traversing the whole mass from a beginning to an end? The answer is a distinct affirmation of the second alternative to the exclusion of the first, with the additional and unexpected rider that the contraction begins at the apex and terminates at the base.

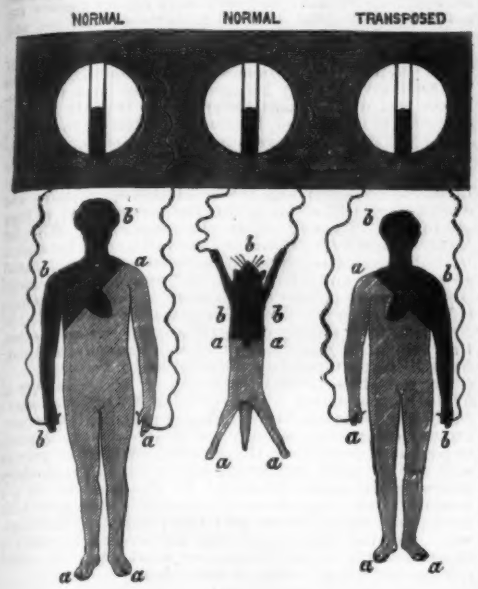
I have tried to sketch out in language as little technical as might be the scope and outcome of a physiological research. I fear—nay, I am sure—that to many of my audience it has been dry and tedious, yet I cannot but hope that some of you have been interested to hear by an actual example what kind of work goes on inside a physiological laboratory. That has been on the learning side. I should like to touch upon the teaching side.

We may take for granted the importance of physiology in medical education; you have, apart from all higher considerations, a very prominent and tangible sign in the still growing requirements of every examining board, on the Embankment as well as at Burlington House.

Your chief stumbling block is in the indefiniteness of the subject. You are expected to show that you understand certain sequences and relations between the chief functions of the human body, and that you remember a list of facts, laws, numbers, formulæ, and germane opinions. Now it generally happens when a man sends in his schedules that he distrusts his memory rather than his understanding; but I am well assured

* Dr. Waller, who has kindly given us permission to republish his address in full from the columns of the *British Medical Journal*, wishes it to be known that the electrical indicator referred to is Lippmann's capillary electrometer.—EDS. ELEC. REV.

that failures are far more due to unconscious errors of understanding than to conscious errors of memory. What I have termed the sequences and relations in physiology are the silent river; the strings of letters, figures, and words are the brawling torrent! This is exactly as it should be, for the silent stream is a better test of a man's swimming capacity than the shallow torrent.



To drop metaphor—the great sequences and relations between the parts of a living body, by their very indefiniteness, form the best possible ground on which to test judgment and acumen before memory, just the qualities by which you will have some day to distinguish, weigh, and guide physiological factors which hang together labeled with the name of a disease.

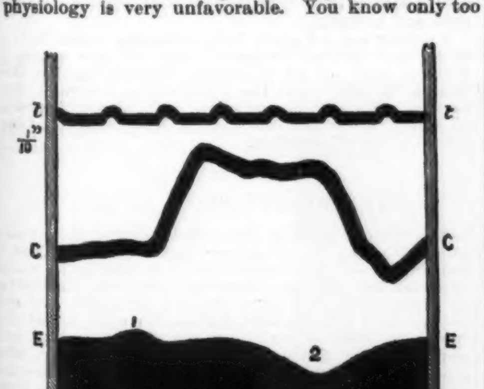
If you learn to see clearly and to move freely in the half lights of physiology, you will see better and blunder less when you have to act in the quarter lights of medicine.

I do not intend to refer in any great detail to particular examinations, but, still confining myself to physiology, I will allude to them for a particular purpose. The first and second examinations of the conjoint board are the first two tests which you all submit to, and I think it is becoming more and more your custom not to give a very bulky precipitate of failures from St. Mary's. I gather from the Dean's statistics that the St. Mary's share of the precipitate is very small in comparison with that which it contributes to the filtrate. Taken all in all, the tests are reasonable; the quality of book knowledge and of practical work required is sensible and moderate.

But, London? It would appear as if the regulations for the intermediate M.B. were designed with the special purpose of preserving the ordinary London graduate from any practical acquaintance with physiology. The regulations set forth that practical work in physiology is required only by candidates for honors and not by candidates for the ordinary pass. A little further, under the heading of organic chemistry, they supply the astonishing item of information that an estimation of sugar or of urea may be required in the honors examination.

As if still further to insure that the ordinary candidate may have a fair chance of muddling his physiology by neglecting it in season and cramming it out of season, when his whole attention should be concentrated on medicine and surgery, the regulations provide that "any candidate shall be allowed . . . to postpone his examination in physiology . . . until the next or any subsequent year."

The effect of these regulations upon the study of physiology is very unfavorable. You know only too



C C = cardiogram. E E = electrometer tracing.
$t\,t$ = time in tenths of a second.

well that practical physiology is not wanted at the examination, and you do not believe that it is wanted for the examination quite apart from any ulterior value it may possess to you. You look upon practical physiology as a luxury, and you do without it. You are told that an estimation of urea or of sugar may be required at the honors examinations. What more natural than that a pass candidate should think it ridiculous waste of time to learn to estimate sugar and urea by doing so when he can read about it in any book? But I would have you remember this, that although the London University by implication advises you so badly, yet it does not expect you to act upon the advice—quite the contrary. Although as a matter of convenience, practical work is not wanted at the pass examination, there is no examination at which its value is more felt, both in the written paper and still more at the *viva voce* interview which follows it. The reason is obvious; the examiners you have the pleasure of meeting there are men whose lives are spent in laboratories, and whose conversation when you meet them at Burlington House is apt to be more practical than scholastic. To put it low, book talk, unleavened by any memories of the laboratory, does not pay; and as for the written paper—well, fireside anatomists are not apt to give very clear or very correct descriptions; fireside physiologists write perfect balloons of unsubstantial statements.

I have seemed to make examinations the end-all of your students' career, but I need hardly say that I look beyond them; the proof of a picture is in the selling of it; the proof of a student is in the passing of him. These are rough tests which mark out good pictures and competent men. I should hardly have made such a point of practical physiology had I not been convinced that its importance extends beyond as well as up to the time when a man receives his certificate of competency to take charge of lives and limbs.

I would have you convinced from the very outset of your medical studies that examinations and competency in after life are on the same lines—the same road leads to both, and to the success which is the natural and lawful reward of competency. It is the royal road of actual contact with facts which tempers men as fire tempers steel. Your way lies through the dissecting room, the laboratory, and the hospital ward more than through the lecture room and the printed book. It is something, no doubt, to be learned, to be well filled with the knowledge of what other men have thought, said, and done; but mere learning is an invertebrate; contact with facts gives it backbone, and makes all the difference between the bookworm and mental vertebrate man. And it is the same royal road that leads on to that well grounded consciousness of power, to that fertility of practical resource in the face of danger; above all, to that "never say die" spirit, which is the best of drugs—best for your patients, best for their doctors, best, indeed, for every man and woman with duties and purposes to fulfill.

Note.—The diagrams used in the lecture were in red and blue. In the woodcuts as printed, red is light shading, blue is dark shading. In the third diagram red is in plain lines, blue in dotted lines.—*Electrical Review.*

[Continued from SUPPLEMENT, No. 672, page 10740.]

ON THE CAUSES OF VARIATION IN ORGANIC FORMS.*

By C. V. RILEY.

EXTERNAL CONDITIONS.—By external conditions or environment, we include all influences on organisms which act from without, and in carefully considering them we shall find it difficult to draw the line between those which are really external and independent of any motive or inherent tendency in the organism and those which are not. Hence, the general term "External Conditions" is resolvable into various minor factors. Considering the influences as a whole, we find that in the 1844 essay, or sketch, Darwin gave more weight to them as producing variations, and as modifying habit, than he did in the "Origin;" yet we all know that he felt convinced, when this work was first issued, that natural selection was the main, though not the exclusive, means of modification. Before his death, he was again led to attach greater importance to them.

As late as March, 1877, he wrote to Neumayr, of Vienna, that "there cannot be any doubt that species can be modified through the direct action of the environment. I have some cause for not having more strongly insisted on this head in my 'Origin of Species,' as most of the best facts have been observed since its publication." He was led to this modification of his views by Neumayr's essay on "Die Congerien," and by Hyatt's work in showing that similar forms may be derived from distinct lines of descent. In his correspondence with Huxley, Darwin remarks that one point has greatly troubled him. If, as he believed, accidental conditions produced little direct effect, "What the devil determined each particular variation? What makes the tuft of feathers come on the cock's head, or moss on the moss rose?"

It is quite plain, indeed, that subsequent to the publication of the "Origin," and especially in 1862, in his correspondence with Lyell, Darwin was inclined to give more power to physical conditions, and, in fact, was wavering in his mind as to the force of the different influences at work. In his letters to Hooker in 1862, the same tendency may be noted, and the preparation of the "Variation of Animals and Plants under Domestication" led him to believe rather more in the direct action of physical conditions, though he seemed to regret it because it lessened the glory of natural selection and, to use his own language, "is so confoundedly doubtful." One can plainly trace from the correspondence how, prior to the publication of the "Origin," he more and more, as his facts accumulated, and as the theory of natural selection grew upon him, relegated to an inferior place the influence of environment; while, subsequent to the publication of that work, and up to the time of his death, the tendency seemed to be in the opposite direction.

Many eminent workers have differed greatly from Darwin in the influence allowed to these external conditions, and this is particularly the case with our American writers. Indeed, no one can well study organic life, especially in its lower manifestations, without being impressed with the great power of the environment. Joseph LeConte speaks of the organic kingdom lying, as it were, "passive and plastic in the moulding hands of the environment." Leidy, Wyman, Clark, Packard, etc., have insisted on the influence of physical conditions. Baird and Ridgway on geographical distribution, Whitman on concrescence, Hyatt on gravitation, Cope and Ryder on mechanical stress, have all published valuable corroborative evidence; while many other writers have added their views and testimony, which have been admirably condensed by Professor Morse in two addresses before this Association.

Allen demonstrates plainly the influence of climate and temperature in directly inducing specific changes. Weismann, in his remarkable "Studien der Descendez Theorie," concludes that differences of specific value can originate only through the direct action of external conditions, and that allied species and genera, and even entire families, are modified in the same direction by similar external inducing causes. In Semper's "Animal Life" (1877) we have the best systematized effort to bring together the direct causes of variation, and no one who has read through its pages can doubt the direct modifying influences of nutrition, light, temperature, water at rest and in motion, atmosphere still or in motion, etc., or question his conclusion that no power which is able to act only as a selective and not as a transforming influence can ever be exclusively put forth as a *causa efficiens* of the phenomena. Kolliker, in 1872, wrote: "Manifold external conditions, when they operate on eggs undergoing their normal development, on larvæ or other early stages of animals, and on the adult forms, have produced in them partly progressive and partly regressive transformations," and recognized as most important forces nutrition, light, and heat. Indeed, the direct action of environment must have been, as Spencer puts it, "the primordial factor of organic evolution."

In so far as it offers evidence, entomology confirms the conclusions of the writers in other departments of natural history, above referred to, and offers a host of most conclusive proofs of the direct action of the physical and chemical factors which I have enumerated. Justice, however, could not be done to the facts within the limits of an address of this kind, and I pass on to some of the other factors.

It is among what I have called the vital or organic conditions of variation that natural selection has fullest sway, and as they have been so ably expounded by Darwin and others, they may be dealt with in few words.

Interaction of Organisms.—The productions, as a whole, of greater areas will, whenever they get an opportunity, conquer those of lesser areas, and in this broad sense the interaction of organisms may be said to have had no special modifying power, however great its influence may have been, and is yet, in inducing the survival of the fittest or in bringing about the present geographical distribution of species. The consequences of enforced migration and isolation are best considered when dealing with the physical conditions, because they must influence modification of masses rather than of individuals, and either substitute one type for another or remove competing or differentiating influences.

But in the more restricted sense, *i. e.*, the interaction of organisms occupying the same ground, the struggle for existence, in other words, between direct competing organisms, is a prime Darwinian factor of modification, and a whole volume of illustrations may be drawn from entomology; for in no class is the contest more severe, whether with plants or with other animals or with one another, than in insects. In no other field of biology, for instance, have the physical conditions resulted in such infinite diversity of form and habit fitted, whether for earth, air, or water, and often for all in the same individual; so, also, in no other field is parasitism carried to such a degree, or are the purely adaptive structures due to this interaction so varied or so remarkable. The entomologist who goes beyond the "dry bones" of his science is inevitably a Darwinian.

In this category must also be included that interrelation between insects and plants which has eventuated in the so-called carnivorous plants, and that still more wonderful interaction between flowers and insects by which each has modified the other, and the facts of which have been so untiringly observed and so well set forth by a number of writers from Sprengel's day to this, and by none more successfully than by Darwin himself. These are plainly inexplicable on external conditions acting on masses alike, and are meaningless enigmas except on the theory of natural selection or some supranatural and dogmatic gospel.

We are thus led, through this last, from the external to the internal factors in evolution, or those of a physiological and psychical nature. In these, natural selection is the key which, so far, best unlocks their meaning and shows how they have acted in the formation of species and the less fundamental of the great groups. In considering them it is hardly necessary to discuss their relative importance as compared with the external conditions, though it may be remarked that they are the factors which have induced the great variety of adaptive forms and minor differentiations, while the external conditions have governed the formation of the great and more comprehensive types of structure.

Darwin was led to give more importance toward the end than he had originally done to some of these internal factors, and especially to functionally produced modifications. In the "Descent of Man" he says that he did not sufficiently consider variations "which so far as we can at present judge are neither of benefit nor injurious; and this I believe to be one of the greatest oversights I have yet detected in my work." And in the sixth edition of the "Origin" he frankly admits that he had omitted in other editions to consider properly the frequency and importance of modifications due to spontaneous variability. He further refers to morphologic differences, which may have become constant through the nature of the organism and the surrounding conditions rather than through natural selection, since they do not affect the welfare of the species. In short, Darwin's views kept pace with the investigations of his day, and tended in the direction of restricting rather than widening the influence of natural selection. But, as Romanes, and especially Spencer, in his "Factors of Evolution," have fully shown Darwin's position on this subject, I may pass over the detail.

INTERNAL CONDITIONS—*Physiological.*—*Genesis* itself is the first and most fundamental of all causes of variation. The philosophy of sex may, indeed, be sought in this differentiation, as the accumulated qualities in separate entities when suddenly conjoined or commingled inevitably lead to aggregation and heterogeneity—in other words, to plasticity, or capacity to vary. Genesis, as a fundamental factor in evolution, may be more intelligently considered under some of its subordinate phases, as heredity, physiological selection,

* Address by C. V. Riley, vice-president, section F, before the section of biology, American Association for the Advancement of Science, at the Cleveland meeting, August, 1888.

sexual selection, primogenital selection, sexual differentiation, including philoprogeneity, hybridity, etc.

Heredity, as expounded by the ablest biologists and as exemplified in life, is a puissant factor in evolution, and, though essentially conservative, must, through the marvelous power of atavism, tend to increase individual variability. The subject has been too well considered by Darwin and his followers to justify further discussion of it here. As a cause of variation, heredity must, however, have less and less influence as we go back in the scale of organized beings; for it cannot well come into play in agamic or fissiparous reproduction—a fact which has given the abiogenesists one of their strongest arguments, since it is difficult to understand how, for instance, the monera of to-day could have descended without change from the primordial form.

Physiological Selection.—Physiological selection, as suggested by Mr. Catchpool and as expounded by Romanes, is undoubtedly a veritable factor in evolution, and while giving us another link in the chain of evidence as to the causes of differentiation, lessens in but very slight degree the overwhelming force of the argument for natural selection. It adds, rather, an important element in the evidence therefor, and may be classed as a subordinate cause of differentiation. Romanes' theory is based upon the argument that differences, such as constitute varieties and species in their commencement, would not be preserved by natural selection unless useful, but would be lost again by cross breeding with forms like the parent, and which had not varied, except upon some hypothesis like that of physiological selection. This could not be prevented except by migration. This difficulty is a general one, was argued by Darwin himself, and has been felt by all Darwinians. The reproductive organs are extremely variable, and sterility may occur not only between species, but between races and varieties and often between individuals. Physiological selection tends to form varieties by peculiarities in the reproductive system of individuals which render them unfit for perfect coition, or cause them to remain more or less sterile, with other individuals which have not the same peculiarities.

The exact reasons are recondite, and the whole subject difficult of demonstration except from the results, since changes in the reproductive organs are not easily observable. Romanes believes this sterility to be incidental to variation and hence one of the chief causes of the accumulation of such variation. Wherever there has been modification of the reproductive organs introducing incompatibility between two individuals, even where there has been no other change or variation, we have a valid cause of differentiation which in its consequences must be important. Compatibility or fertility between individuals is of the very essence of selection. Natural selection implies that this sexual divergence is subsequent to or coincident with divergences in other directions; physiological selection, that it antecedes them. To put the case of Romanes more fully, we will suppose that among the natural variations there occasionally occurs something to affect the reproductive organs in such wise as to produce incompatibility, *i. e.*, incapacity of one individual with another of the parent type to unite, or sterility of such union, while it remains fertile with the variation of its own kind. This theory of course implies variation in the reproductive organs, or departure from the parental type, in at least two individuals of opposite sex simultaneously, and with this admission, for which we are justified in facts, physiological selection will preserve many peculiarities which need have no necessary connection with the exigencies of life.

The change may be in the organs of reproduction, introducing sexual incompatibility, or it may be due to other causes, as, for instance, the time of flowering in plants, or the season of heat in animals. Even the element of scent becomes important here, as my friend J. Jenner Weir has suggested, since it may influence sexual relationship, so that the very excretions of the body, which vary with individuals, must be allowed their part. Francis Galton has indicated a modification of Romanes' views, viz., that the primary characteristic of a variety resides in the fact that the individuals who compose it do not care to mate with those outside their pale. Incipient varieties are thus thrown off from the parent stock by means of peculiarities of sexual instinct which prompt what anthropologists call endogamy, and check exogamy or marriage without the tribe or cast. This is a very good anthropological illustration of how physiological selection may begin.

Natural selection preserves the individual best adapted to life conditions by destroying the less fit. Physiological selection may be said to preserve differences which have no necessary connection with the necessities of life. Neither touches the origin of the variation, but both express laws thereof or methods by which it is accumulated. The inherent tendency to vary, whether in external or adaptive structure, or internal or reproductive character, is simply an observed fact, the causes of which we are endeavoring to analyze.

Physiological selection is remarkably exemplified in insects, and probably in no other class are the modifications which may be attributed to it more easily studied; for in no other class are the genitalia of the male so variable or so complex. There has so far been no attempt to homologize the different parts in the different orders of insects, so that they have received different names according to individual authors. Ordinarily there are two pairs of claspers, themselves very variable, associated with sundry hooks and tufts of hair. There are families, as in the Cecidomyidæ, among the Diptera, in which many species are almost, and others absolutely, indistinguishable except by the differences in the male genitalia. In all other orders there are an immense number of forms which can only be distinguished by a careful study of those organs. Descriptive entomology to-day which does not take account of these organs is, in fact, almost valueless, and we must necessarily assume that where there is differentiation of structure in these important parts it implies a corresponding modification on the part of some associated female even where no other differentiated characters are to be detected, and upon Romanes' law such must be looked upon as physiological varieties, and will be counted good species in proportion as the differentiation involves other observable characters or as their life habits determine.

Sexual Selection.—The part of sexual selection in inducing variation may next be considered. While it is evidently at the bottom of the diversity in sex so common among many animals, it is difficult to see how it can play any very important part in the differentiation of species, except on the hypothesis that the greater the differentiation between the sexes, the greater the tendency to vary in the offspring. In no class of organisms is this factor more notable than in insects, and volumes might be written to record the interesting and curious facts in this class alone. As a general rule, it may be said that with insects, as with other animals, it acts chiefly in inducing secondary sexual characteristics in the male, and in simplifying the characteristics of the female. Nowhere do we find greater contrasts between the sexes, involving almost every organ, both colorationally and structurally. Where color is affected, the greater brilliancy almost always belongs to the male sex, as in birds. So where song or sound is employed to attract, the sound organs are either peculiar to or most highly developed in the males. As in higher animals, also, so in insects, we find offensive organs highly developed in the male, and either lacking or but partially developed in the female, wherever the struggle for the possession of the female is by force, or strength. It has evolved scent organs in various parts of the body, causing modification, especially in the Lepidoptera, of either the membrane of the wing or the scaly covering; it has induced profound modification in the structure of the legs, whether the anterior, middle, or posterior pair, and whether in the whole member or some part of it, or in its covering. The subject has been so fully treated by Darwin, however, that it is not necessary to elaborate it further in this connection. Strictly speaking, it may be said to act in two ways, viz., by conflict of the males for possession of the female, or by attractiveness, the former being most conspicuous among mammals, the latter among birds, and both coming conspicuously into play among insects. It is rather difficult to define the limit of sexual selection as a factor in evolution, but I would not confound it with another factor, not hitherto generally recognized, but which I think must be all-powerful, namely, sexual differentiation.

Sexual Differentiation.—It seems evident that the mere differentiation of sex in itself has been an important element in variation. The principle elaborated by Brooks as a modification of the theory of pangenesis is a good one, and in the main the male may be said to be the more complex and to represent the progressive, and the female the more simple and to represent the conservative element in nature. When the conditions of life are favorable, the female preponderates, and exercises a conservative influence. When the conditions are unfavorable, the males preponderate, and, with their greater tendency to vary, induce greater plasticity in the species, and hence greater power of adaptation. Sexual differentiation may, I think, be used to include many other variations and differentiations not otherwise satisfactorily accounted for, and to express the law of the interaction of the sexes upon one another, inducing great differentiation entirely apart from the struggle of the males for the possession of the females, or the struggle for existence. Among insects, particularly, though the same is true among other classes, we find many illustrations of this that can hardly be explained by the other forms of selection.

A few of the more notable in Hexapods may be instanced, as the degraded form of the female in Stylopidæ; in very many Lepidoptera and Coleoptera; in the females of the Coccidæ, in Homoptera, etc. In most of these cases it is the female which has been modified, without any very special modification in the male, though it is a general rule that in proportion as the female is degradational and stationary, the organs which permit him to find her, or to mate with her, and particularly the antennæ, eyes, and genitalia, are profoundly modified and complex. This is especially noticeable in the Psychidæ, where the female remains in her case, a mere mouthless, eyeless, legless, and wingless grub, and the male has most complex and ramose antennæ and complex genitalia. Another remarkable instance may be cited in the Lampyridæ, where we find every degree of degradation in the female, from partial wings to no wings at all, accompanied with increasing complexity of eyes and antennæ in the male, until at last in the Phengodini the female is so larviform that she can hardly be distinguished from the true larva. In all these cases the female has been as profoundly modified as, and often more so than, the male, and in the latter case a phosphorescent power has been evolved, so that the attractiveness, as in the human species, is rather on the female side. Again, in the case of Corydalus, in Neuroptera, the profound modification of the jaws in the male into prehensile sickle-shaped organs is to be explained rather on the interaction between the sexes, and the facility the modification offers for coition, than upon sexual selection in its proper and restricted sense.

In this category must also be included the influence of *philoprogeneity*, which has modified the female rather than the male, either in the primary sexual organs, for offense or defense, as in the sting of the aculeate Hymenoptera; or in the secondary sexual characters, as in the anal tufts of hair, secretory glands, etc., of many Lepidoptera; or in modification of various other parts of the body exhibited in various orders of insects to facilitate provision for their young, whether in the preservation of the eggs or the accumulation of food for the future progeny. A notable instance of how far this may be carried is furnished by the female Pronuba, where the ovipositor and the maxillæ are so profoundly modified as to make her unique in her order. Sexual selection can have little to do with these modifications, cases of which might be multiplied indefinitely; nor can they be fully explained by natural selection, in the restricted sense in which we have proposed to use it; nor by physiological selection.

In this category might also be included modification which has resulted in the various forms of females which obtain in the same species, fitted whether for agamic or sexual reproduction, and which are far more readily explained on the theory of sexual differentiation aided by environmental influence, especially food and temperature, than upon any other.

Hybridity.—The subject of hybridity has been fully discussed by many, and by no one more ably than by Darwin himself. It has generally been assumed that the hybrid of any two species is sterile, and, in fact, hybridity has been looked upon as one of the best tests of specific value next to genesic incapacity. The assumption finds its greatest support in genesis among the higher animals and the most thoroughly differentiated species; but the whole subject becomes complicated as we descend in the organic scale, and hybrids between what naturalists generally separate as good species are far more frequently fertile among plants and lower animals than was formerly supposed; while physiological selection, as we have just seen, may render genesis impossible, or at least prevent it, between varieties and incipient species.

In this light hybridity becomes an important factor in the modification of species. Unnecessary importance has been given, in my judgment, to the fact that domestic and wild species differ in the fertility of their crosses. It is assumed, for instance, that all the known breeds of domestic dogs would be fertile *inter se*, and produce fertile crosses. It seems to me on the very face a preposterous proposition, and that many of the breeds of domestic dogs are as distinct specifically, and even generically, so far as this test is concerned, as they are in structure and other characteristics. Who, for instance, has ever known or heard of a cross between a bull dog and a lap dog, or between a Newfoundland and a black and tan? The difference in size alone would seem to render such a cross, if not a physiological or a physical, at least a practical impossibility; so that hybridity among domestic animals tends to essentially the same result as among wild animals, and confirms its importance as a differentiating factor.

Having thus summarily indicated those factors of evolution associated with genesis, and which are essentially physiological, however much psychical phenomena may co-operate, we may touch upon the more purely psychical factors, or those pertaining to the growth and use of mind, employing the term to express those neural phenomena traceable to the medium of the brain. Their importance in evolution increases with increasing cephalization and complexity of nerve system. For the present purpose, however, it is with the objective side of psychology, or what may be called psycho-physiology, that we must deal.

(*To be continued.*)

BEAUTIES IN COMPETITION.

THERE is a goodly number of persons who would be only too glad to be on a jury selected for the purpose of distributing prizes for beauty; but there are probably few who know in what the duty of a jury of this kind consists. The competition that has just taken place at Spa has established precedents in this regard.

The organizer of the competition was Mr. Herve du Lorrain, who, a long time before the war, was the first to conceive the idea of opening a salon for rejected paintings at Paris. The administration of the Casino of Spa put at his disposal $2,000, which were to be divided among the three women declared the prettiest by a jury composed of twenty-two persons of the masculine gender, the competency of whom was admitted—in principle.

To prevent a crowd, the candidates were obliged to first send their photograph. All commonplace faces were thrown out, and only the non-similar beauties were retained. These, to the number of twenty-one, were called to Spa for the competition, properly so called, the administration of the Casino assuming all the traveling expenses.

The candidates were quartered in the annex of a hotel specially secured for them, and which they only left in close carriages to reach the grand hall of the Casino, where the examination took place. This latter lasted twelve days.

Upon a stage stood the beautiful Fatima (put out of competition), surrounded by her orchestra and in her usual costume. At the foot of the stage was arranged an orchestra of Viennese ladies. The members of the jury walked around gravely among this assemblage of pretty women, examining them attentively, and, for the prizes to be awarded, taking into account not only the absolute beauty of each one, but also her gracefulness, bearing, toilet, etc.

On the twelfth evening, the jury proceeded with great pomp to distribute the prizes. All Spa was illuminated, and the bourgmaster and authorities were present at the gallant solemnity. Each of the laureates, called in turn by the president, came to get her prize and a diploma.

The first was a French lady (from the colonies, it is true), Miss Marthe Soucaret, aged 18; the second a Flemish lady, of an originally Spanish family, Miss Delrosa Angele; and the third was a Viennese, Miss Stevens. Finally, five prizes of $100 also were awarded, one of which was obtained by Miss Nadiaska Olga, a Swede.—*L'Illustration.*

THE BEAUTY SHOW AT SPA.

THE beauty show at Spa hardly attracted so many competitors as its promoters had hoped. At first it was announced that nearly four hundred ladies would enter the lists, but only nineteen presented themselves for judgment. The show lasted a fortnight, and was held at the Casino, where, for an entrance fee of five francs, the various claimants could be inspected and criticised. On the eventful day when the jury, who numbered twenty-two of the sterner sex, under the presidency of Baron De Mesnil, were to announce their decision there was much excitement, both on the part of the public and, naturally enough, on that of the ladies concerned. The ladies, who were all dressed in ballroom costume, entered the hall in a species of procession. There were eight prizes. The first (£200) was awarded to Mlle. Marthe Soucaret, a French Creole from Guadeloupe, who is eighteen years of age; Miss Delrosa Angele, of Ostend, aged sixteen, receives the second prize (£80); and Miss F. Marie Stevens, twenty-three years of age, of Vienna, the third prize (£40). The other six, who received £10 apiece, were successively Miss Betty Stuckart, twenty-seven years of age, from Vienna; Miss E. Lodz Nadia, aged eighteen, from Lyons; Miss Wilma Arany, nineteen years of age, from Buda-Pesth; Miss Nadiaska Olga, twenty-one years of age, from Stockholm; and Miss Marthe Vilain, aged twenty, from Paris. The announcement caused great wrath among many of the disappointed damsels, some of whom vented their ire in a not wholly becoming manner.—*London Graphic.*

MLLE. SOUCARET, FIRST PRIZE, $1,000.

MISS ANGELE, SECOND PRIZE, $400.

FRAULEIN STEVENS, THIRD PRIZE, $200.

FRAULEIN STUCKART, FOURTH PRIZE, $50.

THE RECENT COMPETITION FOR BEAUTY AT SPA—THE PROCESSION OF BEAUTIES AT SPA.

THIMONNIER, INVENTOR OF THE SEWING MACHINE.

IF you would inquire from some one of the numerous people now using the sewing machine, Who is the inventor of the sewing machine? every one, accustomed as he is to see everywhere the pictures of Elias Howe and the gigantic S of the Singer Sewing Machine Co., would undoubtedly answer you that the sewing machine was devised by American people. Well, indeed, it is not true at all. American people have unquestionably contributed for a large part to endow the sewing machine with the numerous improvements which it has received for some thirty years, but they did not invent it. As early as 1830 a man, a modest tailor, had appeared who had succeeded in building up and running on in an industrial way a sewing machine supplied with a continuous thread and the needle of which was not passed entirely through the cloth, and that man was neither an American nor an Englishman; he was a Frenchman, by name Barthélemy Thimonnier.

English and American people have so many industrial devices of their own invention, that we do not hesitate to take away from them, in behalf of a modest French inventor, who struggled during his whole life, the glory of having devised, built up, and begun to turn out a machine by means of which many manufacturers, Elias Howe, Singer, Wheeler & Wilson among others, secured a very large income.

Barthelemy Thimonnier, whose picture the reader will find below, was the son of a dyer of Lyons and was born at the Arbresle (Rhone), in the year 1793. He studied a little while at the seminary of Saint Jean and was put to the tailor trade, which he practiced at Amplepuis (Rhone), where he had been brought up. Thimonnier, who had many opportunities of seeing the female sock embroiderers working for the manufacturers of Tarare, took into his head to build up a machine so as to perform with it the work of the embroiderer and tailor.

In 1828 he removed to Saint Etienne, and during several years neglected his own business, his only

BARTHELEMY THIMONNIER, INVENTOR OF THE SEWING MACHINE

means of earning a livelihood for himself and his family, and devoted himself in a lonely room to many pursuits and studies, which his friends, as they were unable to understand them, considered at once as foolish. At last, in 1829, after four years' hard work, which, ignorant as he was of mechanics, was the more painful, he mastered his idea, and, in 1830, he applied for a patent for a chain stitch patent sewing machine.

Taken to Paris by Mr. Beaunier, a supervisor of mines, who guessed at first the real value of the invention and became morally and pecuniarily interested in its success, Thimonnier was, in 1831, made a partner and appointed manager of the firm Germain Petit & Co., and set up on Sevres Street, in Paris, a workshop where he used eighty machines, making army clothing.

At this time, the workingmen were adverse to every kind of new machinery, and used sometimes to break it spiritedly, as the boatmen on the Saone River broke Marquis de Jouffroy's steamboat about twenty-five years before Fulton launched his boat on the Hudson River. Thimonnier's machine shared the fate of the other machines; the inventor was obliged to take flight, and, a few months later, on account of the death of Mr. Beaunier, the partnership with Germain Petit & Co. was dissolved, and Thimonnier returned to Amplepuis, in 1832. In 1834 he went back to Paris and, as a journeyman, ran on his machine, which he was always studying to improve.

In 1836 he was penniless and obliged to go once more to Amplepuis; he went on foot, carrying his machine on his back, and to earn his living during his journey he made a show of it as a curious piece of mechanism. He manufactured at Amplepuis a few machines, which he sold with a great deal of trouble in his neighborhood; in 1845 his machine would run at a rate of 200 stitches a minute. He made then a partnership with Mr. Magnin, and built in Villefranche some machines which he used to sell at the derisive price of fifty francs apiece; and on August 5, 1848, jointly with Mr. Magnin, he applied for an improvement patent for his machine which he called "Cousobrodeur" (English patent was applied for on February 9, 1848), and which he no longer made of wood, but of metal, and with accuracy.

The revolution of 1848 having stopped Thimonnier's business, he started for England, where he stayed a few months, and sold his patent to a Manchester firm.

At the exhibition at London in 1851, on account of inexplicable bad luck, Thimonnier's machine was not ready for the examination of the commissioners; whereas the Americans exhibited their first improvements to Thimonnier's machine and the shuttle and two-thread machine of Elias Howe; as early as 1832 Thimonnier had studied this kind of machine, and was yet studying it in 1856. But, exhausted by thirty years' struggling and suffering, he died penniless at Amplepuis on August 5, 1856, leaving a widow and several children. Later, in 1866 and 1872, the French government, at the request of the Industrial Sciences Society of Lyons, relieved by its subsidies the last days of that poor widow, who died on August 9, 1872.

The Board of Commissioners of the Exhibition of Paris in 1855 wrote the following about Thimonnier's machine: "Thimonnier's machine was evidently the standard of all the modern sewing machines," and they bestowed on Thimonnier-Magnin's "Cousobrodeur" a first-class medal; the prize was well deserved, as the "Cousobrodeur" of 1855 was by far superior to the machine of 1830, which, made of wood and put in motion directly by a cord, was unable to make more than one stitch at each oscillation of the treadle.—*Sewing Machine World.*

HANDLE kerosene, benzine, and gasoline by daylight only. Where gasoline is stored, see to it that there is ventilation from beneath, as the vapor from it, which is highly explosive, is heavier than air, and will not ascend, but must be allowed vent below. If these precautions are observed closely, the danger of fires from these inflammable fluids will be reduced to a minimum.

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